# Diagnostic Study for the Development of Pottery Industry Cluster at Khurja in Uttar Pradesh

*Prepared for*

Office of the Development Commissioner (SSI),
Ministry of SSI, Agro & Rural Industries,
Government of India

TERI Project Report No. 2000CR61

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# Contents

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Acknowledgement

Executive Summary

Chapter 1
Introduction ........................................ 1 - 2

Chapter 2
Cluster information ........................................ 3 - 25

Chapter 3
Methodology for unit selection ........................................ 26 - 27

Chapter 4
Review of past studies for Khurja pottery sector ................ 28 - 38

Chapter 5
Problem areas and remedial measures in raw material preparation ..................... 39 - 69

Chapter 6
Problem areas and remedial measures in kilns ................... 70 - 97

Chapter 7
Detailed strategy for implementation ................................ 98 - 103

Annexures

# Acknowledgement

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We gratefully acknowledge the role of Centre for Glass and Ceramic Research Institute (CGCRI), Khurja Centre for contributing the section on 'raw materials preparation'. Particular mention is due to Dr A K Gupta and his team at Khurja in compilation of this section and in coordination of the numerous field visits of the TERI team.

Special mention must be made of the support and cooperation received from Khurja Pottery Manufacturers Association (KPMA), the local industry association without whose help the present study could not have been possible. We welcome this fruitful new collaboration between KPMA and TERI and are confident of our future partnership. The time and effort of Shri S C Khanna, President – KPMA and the management of the participating pottery units in this study is deeply appreciated. Last but not the least, special thanks is due to Shri R K Yadav, Pottery Development Officer, Khurja, who in spite of his busy schedule, provided useful inputs to the project team.

# Executive Summary

Khurja pottery cluster is engaged in the production of various types of ceramic products such as stoneware and bone china crockery, HT and LT insulators, sanitary wares, decorative wares and chemical porcelain. The cluster comprises of dependent and independent pottery units. The independent pottery manufacturers have integrated production facilities ranging from raw material processing to firing. Both dependent and independent potters have their own associations viz. KHPA (Kutir Avam Hasth-shilp Potters Association) and KPMA (Khurja Pottery Manufacturers Association) respectively. The ceramic production from the cluster remained static at low levels till mid 80's and only after mid 80's started witnessing higher growth rates. The annual turnover from existing 515 units at Khurja amounts to Rs 150 crore during 1999–2000.

Although international ceramic manufacturing has undergone considerable technological changes over the years, there was technological stagnation in Khurja pottery cluster. Majority of the units at Khurja still uses obsolete technology downdraft kilns that have higher production costs, lower profit margins, higher fuel consumption and higher level of pollution. From mid-1997 onwards, Khurja pottery cluster has witnessed adoption of energy efficient oil-fired tunnel and shuttle kilns. With regard to raw material processing, the units at Khurja use inferior quality of raw materials and do not use scientific methods for raw material processing and fabrication.

Keeping in view the above, the Office of the Development Commissioner, Small Scale Industries (DC, SSI) entrusted TERI for undertaking a diagnostic study for the modernization of the pottery industry in Khurja. The scope of work for this project included the following activities:

- review of past studies conducted on modernization aspects of the cluster;
- assessment of problem areas at each stage of production,;
- identification of remedial measures to overcome the problems; and
- formulation of detailed strategy for implementation.

are likely to get replaced by either tunnel or shuttle kilns. Discussion with KPMA and several entrepreneurs in the cluster brings out this optimism that downdraft kilns would be completely replaced by tunnel/shuttle kilns in next 3-4 years.

Although shuttle and tunnel kilns are relatively new entrants in the cluster, the energy audit of these kilns indicates clearly a large scope for improving their performance. A number of energy conservation measures (including a few housekeeping measures) have been identified, the study has brought out a few incremental technological changes, which when demonstrated, will have a direct and visual impact for possible replication by other similar units in the cluster. Detailed techno-economic analysis was carried out to ascertain the viability of the recommended measures. The shortlist of such implementable recommendations was finalized in consultation with the KMPA and other stakeholders in a workshop at Khurja. Senior officials from the office of the DC, SSI also participated the workshop. The three most promising options for technology demonstration are as follows.

- Reducing deadweight of trolley ( approximate investment Rs 3.1 lakhs; payback ~ 2 years)
- Use of decker plate ( approximate investment Rs. 7.0 lakhs; payback ~ 1 year)
- Improved burner system (approximate investment Rs. 3.5 lakhs, payback ~ 1.7 years)

The above mentioned costs are indicative in nature and actual costs and benefits will vary from unit to unit based upon a number for factors like size of unit, type of product manufactured, existing energy consumption pattern, energy costs etc.

# 1

# Introduction

The Khurja pottery cluster is one of the oldest pottery clusters in the country. It came into existence during the Mughal rule in the Northern India when there was a demand for earthenware in the Mughal kingdom. Its close proximity to both Delhi and Agra, capital cities of Mughal dynasties, ensured a steady demand for ceramic products. Cluster is located at a distance of about 100 kilometers from Delhi. At present the Khurja cluster has more than 500 small-scale units engaged in the manufacture of a variety of ceramic products like crockery, insulators, electrical items, bone china wares, sanitary and decorative items.

Over the years the cluster has changed in terms of its markets, technology and products. However, in post-liberalized markets in India, the Khurja pottery cluster needs to prepare and upgrade itself for the future challenges. The cluster has great deal of commonality in the level of technology, operating practices, and even the trade practices followed by different units. The cluster-based approach to solve the problems faced by the Khurja pottery cluster has the advantage that the chances for replication/dissemination of the outcomes of the study are high and the transaction costs of interventions are low.

Keeping in view the above, the Office of the Development Commissioner, Small Scale Industries (DC, SSI) entrusted TERI for undertaking a modernization program for the pottery industry in Khurja. The scope of work for this project included the following activities: (1) review of past studies conducted on modernization aspects of the cluster, (2) assessment of problem areas at each stage of production, (3) identification of remedial measures to overcome the problems, and (4) formulation of detailed strategy for implementation.

To meet the objectives of this report, the report has been structured to include the following: (1) cluster information – provides broad overview of the cluster, (2) methodology for unit selection, (3) review of past studies for the Khurja cluster – evaluating various recommendations and their implementation status, (4) problem areas and remedial measures in raw material preparation, (5) problem areas and remedial measures in kilns, and (6) detailed strategy for implementation.

For the purposes of this study, TERI made several field visits to Khurja for conducting on-site measurements and holding discussions with various stakeholders. For a sub component of this study, related to raw material preparation, TERI has taken expert help from Central Glass and Ceramic Research Institute (CGCRI), Khurja.

# 2

# Cluster information

This chapter provides background information about different kinds of technologies (for raw material processing and kilns) used in the cluster, types of products produced in the cluster, various institutions/organizations in the cluster and an overview of the dynamics of innovation in the cluster. For several years, the pottery industry in Khurja has been using obsolete technologies in plants and processes. Although, internationally the ceramic manufacturing process has undergone a lot of technological changes over the years, but the pottery units at Khurja have had technological stagnation and they still remain largely labour intensive depending on the skills of the artisans. The growth of pottery units in different time periods in Khurja is shown in figure 2.1.

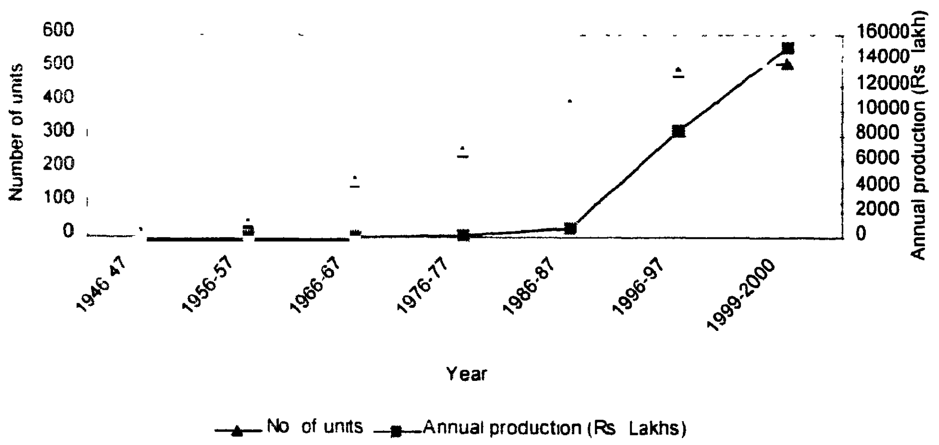

**Figure 2.1** Growth of pottery units at Khurja

As evident from the above figure, the number of pottery units at Khurja has grown steadily from meagre 8 units in the year 1946-47 to 515 units in the year 1999-2000. The annual production from the cluster has however only increased rapidly in last 15 years. This is mainly due to the shift in production towards high value-added products in the cluster and increase in volume of exports.

With liberalization of trade in the years to come and with the imminent invasion of large scale firms in the pottery manufacturing, the small-scale pottery industry in Khurja faces a great challenge. These challenges relate to technology upgradation, process improvements, quality upgradation and market development. It is easy to mirror such concerns in the cluster in the form of recent technological changes occurring in Khurja pottery units. Various aspects of the clusters are discussed in greater detail in the sections given below.

## Constitution of pottery units in the cluster

The pottery manufacturers in Khurja can be divided into two separate categories viz. independent potters and dependent potters (figure 2.2). The independent potters are larger units that have their own integrated operations pottery manufacturing i.e. from raw material preparation to firing of greens. As of January 2000, there are 515 registered independent pottery units of which 491 are operating. The dependent potters on the other hand use common facilities

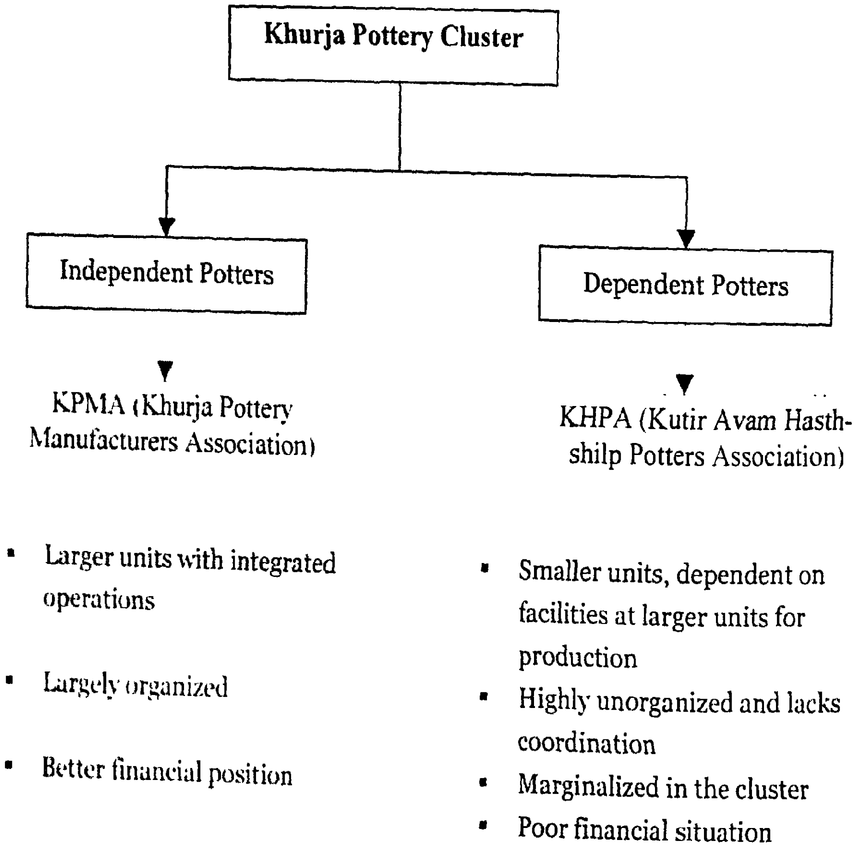
Khurja Pottery Cluster
Independent Potters
Dependent Potters
KPMA (Khurja Pottery Manufacturers Association)
KHPA (Kutir Avam Hasth-shilp Potters Association)
Larger units with integrated operations
Largely organized
Better financial position
Smaller units, dependent on facilities at larger units for production
Highly unorganized and lacks coordination
Marginalized in the cluster
Poor financial situation

**Figure 2.2** Constitution of units in the cluster

provided by the government or carry out part of their manufacturing in their own facilities and rely on other large potters for other operations. The number of registered dependent pottery units were 150 of which only 60 are working. Dependent and independent potters have their separate industry associations. The KPMA (Khurja Pottery Manufacturer's Association) represents the independent potters and KHPA (Kutir Avam Hasth-shilp Potters Association) represents the dependent potters.

The KPMA is well represented by industrial units (presently KPMA has around 350 members) and has taken very proactive approach to highlight the problems faced by the industry with the changing macro environment. KPMA has voiced the concerns of the industry about various related to environmental regulations, power quality, fuel quota, fuel type and export promotion.

The KHPA has been formed very recently in May 2000, to voice the concerns of the unorganized dependent potters in Khurja. Presently, KHPA has about 38 members registered with it. The dependant potters association is trying for some technical and financial support form the government in order to keep the operation dependent pottery units viable and to ensure their survival in long-term.

## Institutions and organizational linkages

To help the development of pottery industry, the government has established several institutions at Khurja. The list of existing institutions in Khurja is given:

Pottery Development Office (PDO)
Central Glass and Ceramic Research Institute (CGCRI), Khurja
High Tension (H.T.) and Low Tension (L.T.) Laboratory
Design Extension Center

PDO is the oldest pottery related institution at Khurja. PDO was established in 1946, to promote the pottery industry in Khurja. Initially the objective of the PDO was to provide training to the entrepreneurs and workers regarding pottery industry. During 1959-60, design extension center, pilot research and processing laboratory and H.T. and L.T. laboratory were established to support the activities of PDO. The objective was to provide the industry with technological support to improve their processes and make available new innovative designs for products. The H.T. and L.T. laboratory was established to provide testing facilities to the units engaged in the manufacturing of electrical insulators.

During the same period, downdraft kilns, potter quarters, and common facilities center had started functioning under the PDO. These facilities were provided to give technical, financial and administrative help to the small and marginalized potters in the cluster (i.e. dependent potters). Figure 2.3, gives an organization chart for dependent potters during the period 1946 to 1982. The CGCRI, Khurja was established in the year 1981 with the objective to provide technical support to the pottery units in the cluster.

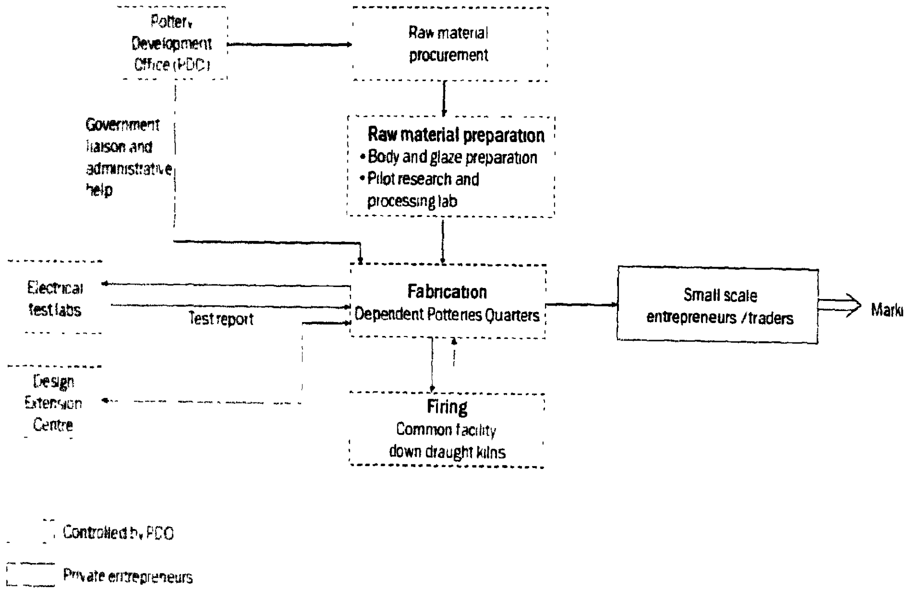
Pottery Development Office (PDO)
Raw material procurement
Government liaison and administrative help
Raw material preparation
• Body and glaze preparation
• Pilot research and processing lab
Electrical test labs
Test report
Fabrication
Dependent Potteries Quarters
Small scale entrepreneurs / traders
Marki
Design Extension Centre
Firing
Common facility
down draught kilns
Controlled by PDO
Private entrepreneurs

Figure 2.3 Organization of dependent potters during 1946 to 1982

Until 1982 the dependent potters used common facilities centre provided by the UP State government to manufacture their goods and sell them to the markets. The facilities for raw material preparation and firing were provided to the small potters on the charge of a small rent for the services provided. The dependent potters were provided small working place for making their goods called "potters' quarters". However, after 1982, the common facilities were transferred to U P. Small Industrial Corporation (UPSIC), Kanpur and the facilities were to be run on a commercial basis. The UPSIC operated the acquired facilities for some time and even made new investments in the form of a tunnel kiln with imported know-how, but later on due to several reasons the production was stopped. Presently, the downdraft kilns, ball mills, etc. under the common facilities are non-functional and the dependent potters rely on a few large pottery units for their operations. In view of this the dependent potters face a great challenge to keep their operation going on in the longer-term.

The present organizational linkage in the Khurja pottery cluster is shown in figure 2.4. As is evident from the figure, the industry has access to technical and R&D institutions in the cluster. CGCRI provides technical help to the pottery units in the cluster and also provides the use of its facilities, on chargeable basis, to the dependent potters. CGCRI also plays a technical advisory role for the pottery units. The CGCRI and Indian Ceramic Society regularly organize training programs for information dissemination and exchange. CGCRI has been taking proactive steps to promote upgradation of the cluster and has prepared several status reports for the cluster. The polytechnic college in Khurja provides the trained manpower to the cluster. Both industry associations (predominantly KPMA) play a very proactive role in voicing the concerns of the cluster at the government forums.

## Types of products manufactured in the cluster

The pottery units manufacture wide ranges of products for both the domestic and the export markets. The domestic market is a major market for the products manufactured in Khurja. Various products manufactured in Khurja include:

- Crockery (stoneware)
- Crockery (Bonechina)
- HT/LT insulators
- Sanitary wares
- Decorative wares
- Chemical porcelain

Most of the pottery units manufacture crockery (stoneware), HT/LT insulators and decorative wares (stoneware). Only a few specialized units are involved in the manufacturing of sanitary wares, bone china and chemical porcelain.

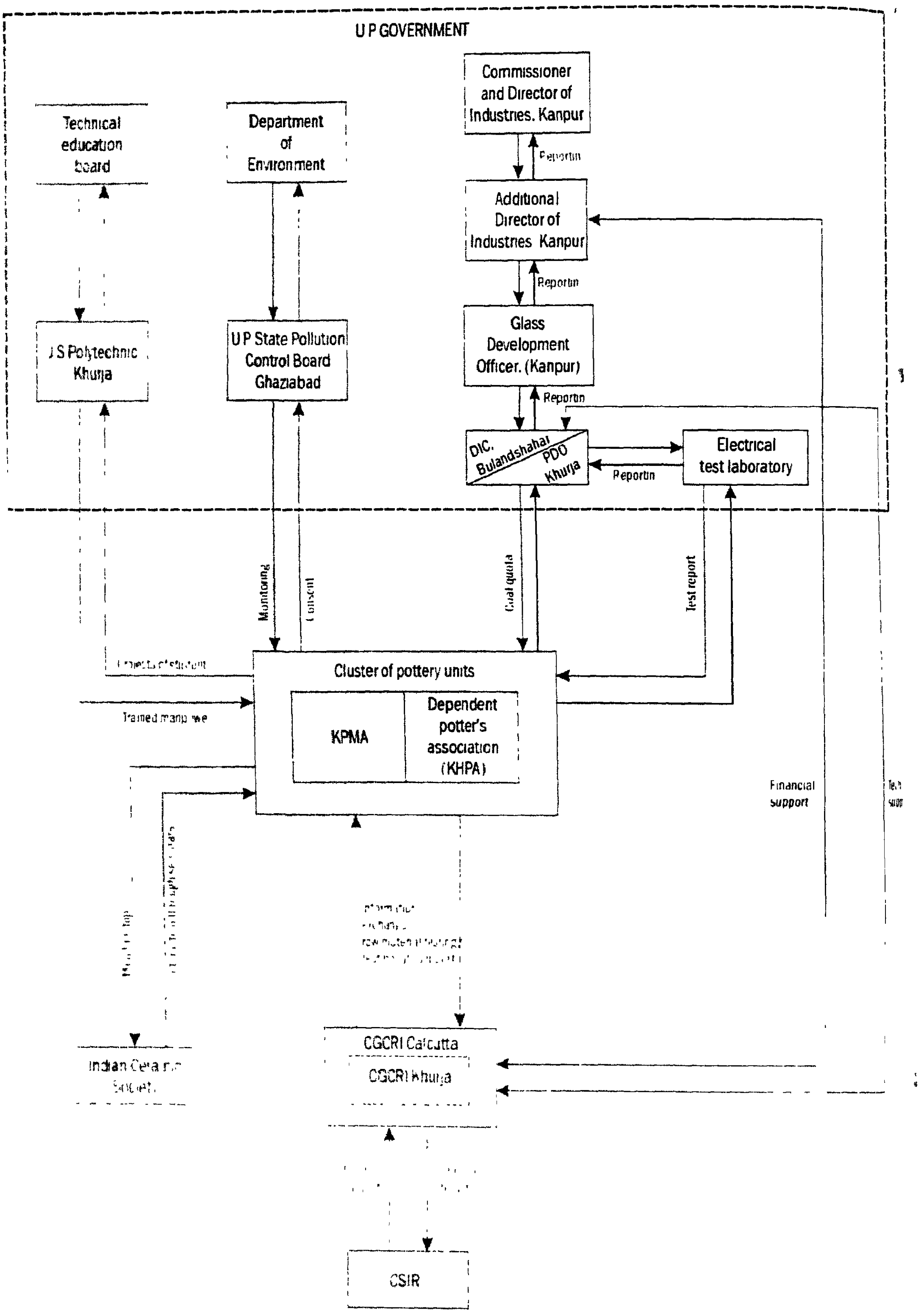
U P GOVERNMENT
Commissioner and Director of Industries, Kanpur
Reportin
Additional Director of Industries Kanpur
Reportin
Glass Development Officer, (Kanpur)
Reportin
DIC, Bulandshahar
PDO Khurja
Electrical test laboratory
Reportin
Technical education board
Department of Environment
J S Polytechnic Khurja
U P State Pollution Control Board Ghaziabad
Monitoring
Consent
Coal quota
Test report
Cluster of pottery units
KPMA
Dependent potter's association (KHPA)
Trained manpower
Financial support
Indian Ceramic Society
CGCRI Calcutta
CGCRI Khurja
CSIR

Figure 2.4 Organizational linkage in the Khurja pottery cluster

## Export orientation of the cluster

The cluster has been exporting its products to world markets, mainly through indirect exports. However, the volume of exports has always remained low, as the units in Khurja cluster are not able to meet the stringent quality requirements of export clients. Table 2.1 shows the recent trend in export from the cluster.

**Table 2.1** Pottery export from the cluster

| Year | Direct export (Rs crores) | Indirect export (Rs crores) |
|---|---|---|
| 1997-98 | 3.0 | 6.0 |
| 1998-99 | 3 75 | 8.25 |
| 1999-2000 | 4 8 | 10 2 |

Source. Pottery Development Office. Khurja

As evident from table 2.1, both direct and indirect exports have increased over past three years. About 23 units are export oriented and out of these units only two are direct exporters. The two units that are direct exporters are very progressive units and have made investments in improving their processes and towards improving the quality of final products. The indirect exporters supply their products to international markets through intermediate agents. When supplying through intermediate agents, the profit margins are lower and there is lack of knowledge and information about the export markets. In such cases the avenues to diversify into new markets and products are severely limited.

There is no local infrastructure support, in the form of inland container depot, banking facilities, export counters for several approvals, etc. are available at Khurja to the entrepreneurs. For export related work there is no single window system available and this is one of the main reasons that the small exporters tend to rely on intermediate agents, which saves the entrepreneurs from a lot of botheration and administrative difficulties that they would have face otherwise. The infrastructure facilities such as roads, telecommunications and power, are very poor in Khurja. Also the housekeeping within the factories is poor that inhibits the units to invite export clients to their units.

*Procurement of raw materials*

The main raw materials used in the pottery units are china clay, plastic ball clay, quartz, and potash feldspar. Types of china clays used are mainly, TT-675, Amrapali, Rajmahal (pink and white), English India, which are procured from various places in Rajasthan, Gujarat, and Bihar. The plastic ball clays are procured from Bikaner (Rajasthan) and Chandia (Madhya Pradesh). Quartz and potash feldspar are procured from Jaipur, Udaipur and Ajmer. Fire clays are procured from Delhi.

There are several auxiliary raw materials and chemicals used in these ceramic units like marble, soda feldspar, zinc oxide, zirconia, barium carbonate and chromium oxide that are used in glazes. Frits of the opaque and transparent type are used in different types of glazes for obtaining better finish and for reducing the maturing temperature of glazes. Chemicals like sodium carbonate and sodium silicate are also used in preparation of casting slip. Plaster of Paris is another important raw material used in the preparation of moulds.

For preparation of saggers, two types of materials are used – plastic fire clay and non-plastic fired clay grog. Broken saggers are also used as grog after disintegration.

Since none of the above mentioned raw materials required for making pottery items are available locally at Khurja, the raw materials are procured through local agents in Khurja. Some entrepreneurs have direct contact with the mines in various states and the raw materials are procured directly from these mines.

## Testing of raw materials and raw material processing

The raw materials received by the units have several impurities that result in number of defects in the preparation of greens and the quality of final product. Therefore, the raw materials should be tested regularly for their properties and composition. Although testing facilities for raw material are available at CGCRI, Khurja, but none of the units regularly test the procured raw materials. Discussion with some pottery owners revealed that they did not face any severe problems due to poor quality of raw materials. However, the unit owners acknowledge the fact that the quality of raw materials varies from batch to batch. Pottery owners are, to a large extent, ignorant of the impact of raw material quality on the final products.

With regard to processing of the raw materials, most of the independent potters have their own raw material processing facilities. Major equipment in the raw material processing include primary and secondary crushers and ball mills, blunger, agitators, magnetic sieve separators, filter press etc. In addition to the quality of raw materials, the processing of raw materials also has significant impact on the quality of final products. In general, various steps involved in raw material preparation and fabrication of stoneware crockery, art wares and LT insulators are shown in figures 2.5, 2.6 and 2.7 respectively. The steps in the process might change according to the type of product being manufactured and the quality of raw material being procured.

China clays, which are generally obtained in the processed form and the lumps are soft, are easily dispersible in water and therefore no size reduction is required. The Bikaner clays are procured in raw form but they are easily dispersed in water. However, Than clays are usually hard and are not easily dispersed in water, so they are required to be treated in a disintegrator.

Quartz lumps are broken after calcination by manual hammering up to 1" to 2" size. Similarly, feldspar lumps are broken into smaller pieces by manual hammering. The crushed raw materials (quartz and feldspar) are charged in the ball mill along with stone pebbles and water for required grinding. To get the maximum efficiency out of the grinding operation, it important to control the proportions of materials loaded in the ball mills and to regulate the size and quality of pebbles charged in the mills.

The raw materials are ground to required fineness of about 250# in the ball mill. Bikaner ball clays are also milled in the ball mills. China clays are blunged in a Blunger. All the ingredients are thoroughly mixed in the agitator. The ground quartz and feldspar slurry is passed through a sieve (or a magnetic sieve) prior to addition in the agitator. The main reason for passing the slurry through magnetic sieve is to remove any iron contamination that can severely affects the final product quality.

After proper mixing in the agitator, the mixed slurry is passed through a filter press by a diaphragm pump to obtain filtered cakes having moisture content in the range of 24-30%. The filtered cakes are passed through de-airing pug mill for removing air from the material and creating a homogenous mass.

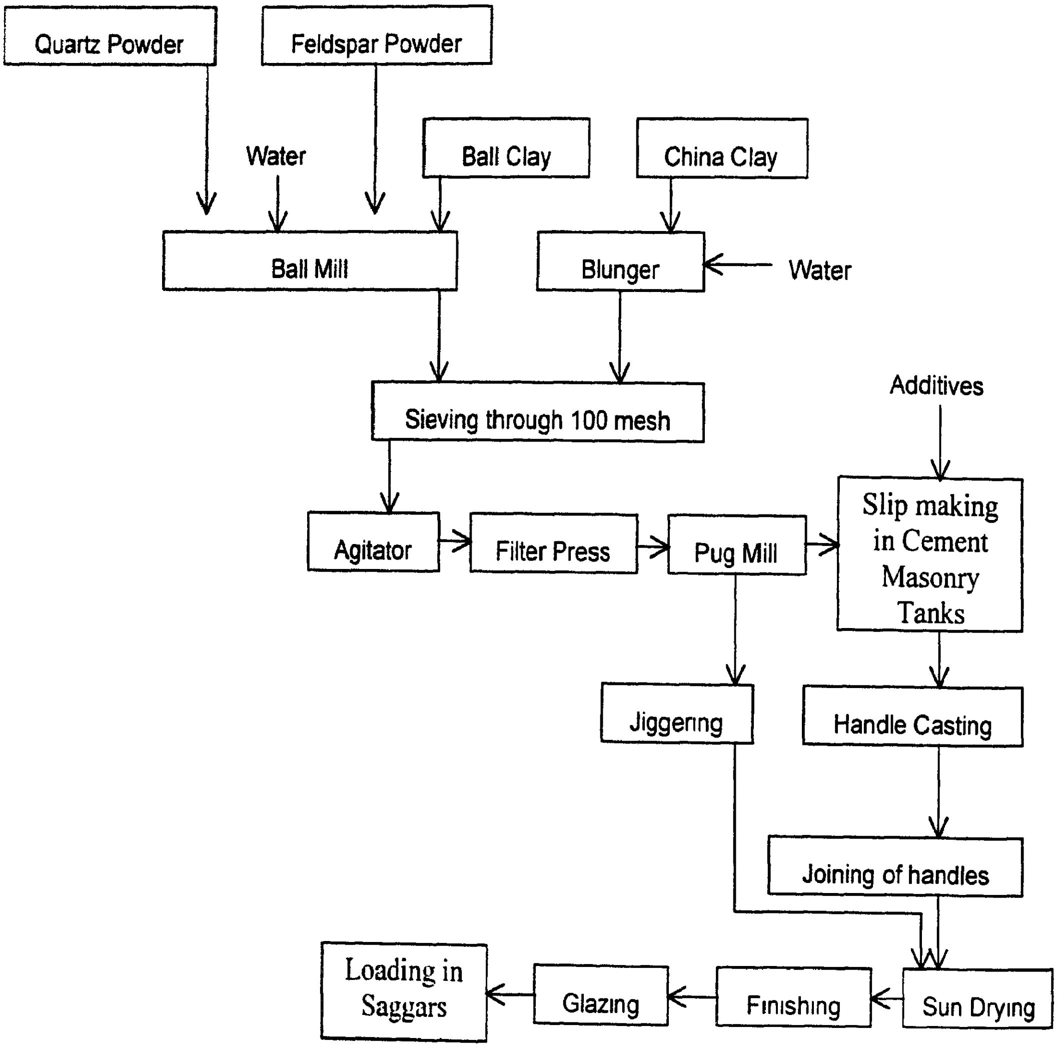

**Figure 2.5** Typical steps involved in raw material preparation and fabrication of stoneware crockery

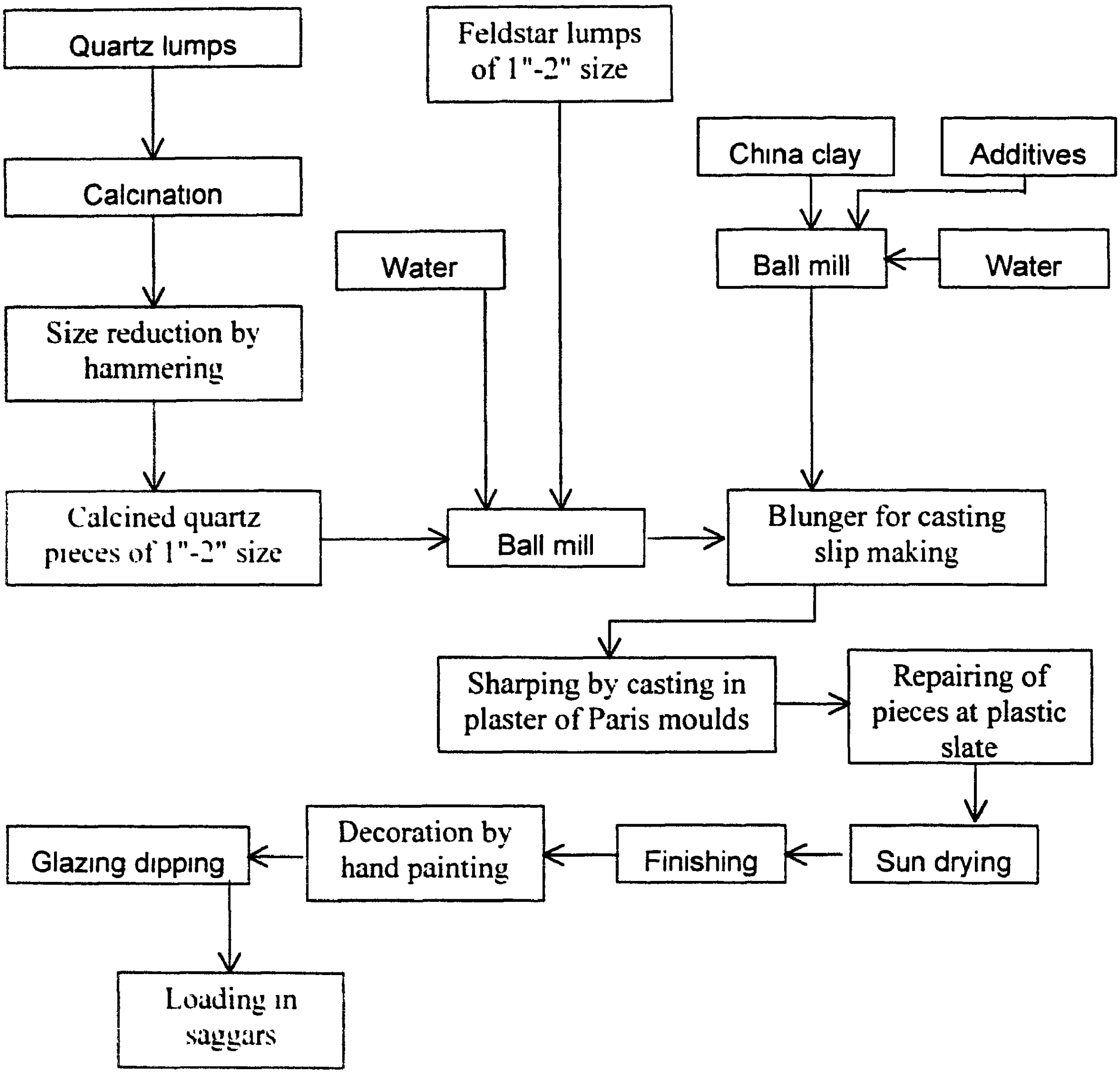
Quartz lumps
Calcination
Size reduction by hammering
Calcined quartz pieces of 1"-2" size
Water
Feldstar lumps of 1"-2" size
Ball mill
China clay
Additives
Ball mill
Water
Blunger for casting slip making
Sharping by casting in plaster of Paris moulds
Repairing of pieces at plastic slate
Sun drying
Finishing
Decoration by hand painting
Glazing dipping
Loading in saggars

**Figure 2.6** Typical steps involved in raw material preparation and fabrication of art-wares (stoneware)

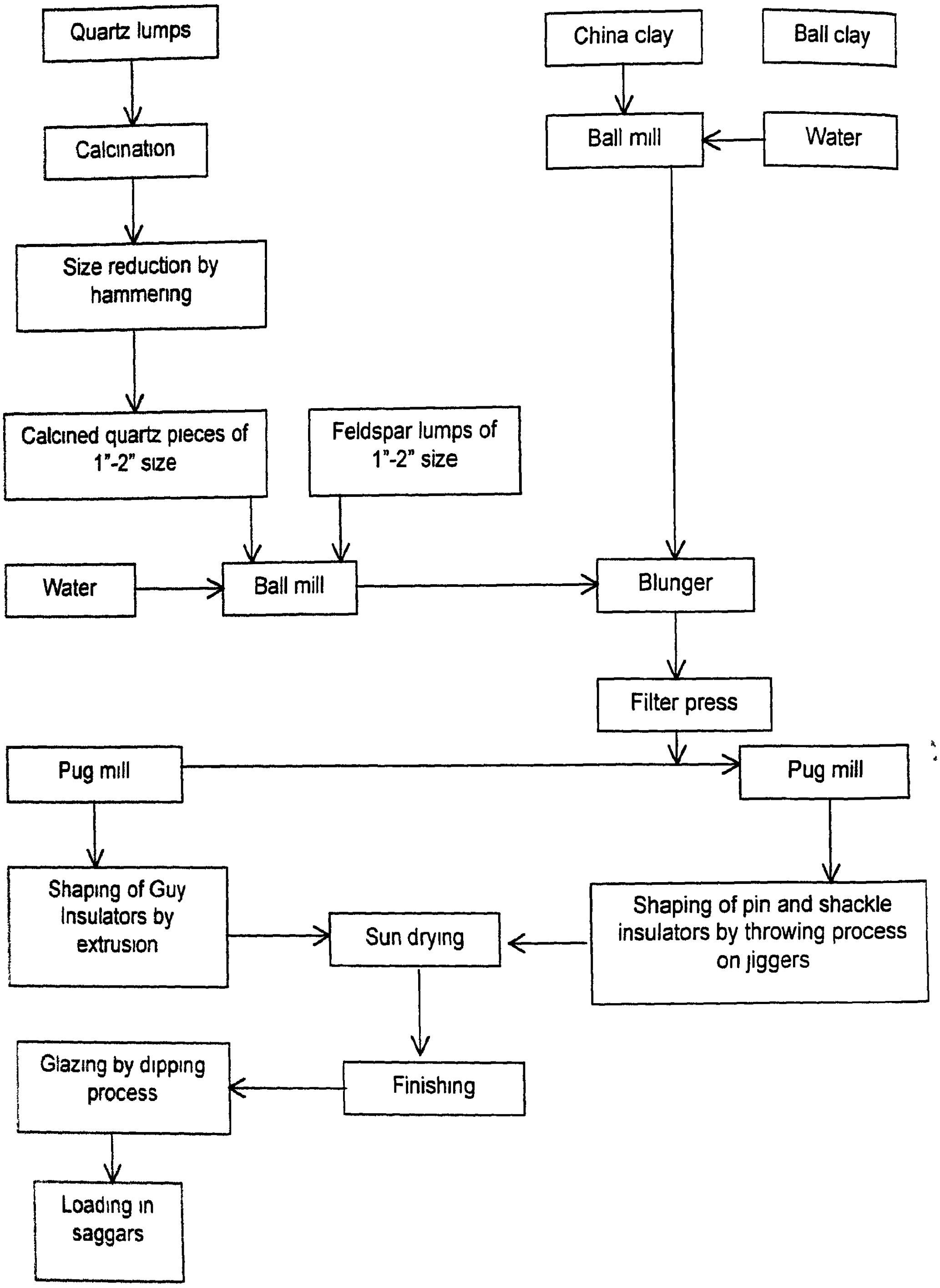
Quartz lumps
China clay
Ball clay
Calcination
Ball mill
Water
Size reduction by hammering
Calcined quartz pieces of 1"-2" size
Feldspar lumps of 1"-2" size
Water
Ball mill
Blunger
Filter press
Pug mill
Pug mill
Shaping of Guy Insulators by extrusion
Sun drying
Shaping of pin and shackle insulators by throwing process on jiggers
Glazing by dipping process
Finishing
Loading in saggars

**Figure 2.7** Typical steps involved in raw material preparation and fabrication of LT insulato

For preparing glazes, potash feldspar, calcined quartz (1"-2" lumps), marble (1/2" lumps), zircon and other materials are charged in a separate ball mill (used only for glaze preparation). The grinding operation in the ball mill is done in two cycles. In the first cycle, the ball mill is charged with materials and pebbles in the ration of 2:1 and water is added without measurement. The materials are finely ground to a fineness of 300#. In the second cycle, zinc oxide, barium carbonate etc. and china clay are added in the same ball mill and allowed to mix further. The finely ground glaze is finally unloaded from the ball mill and passed through a small magnetic sieve and then saved.

## Fabrication of greens

For producing stoneware crockery, materials are given shapes by using the solid homogenous mass in the jigger-jolly machines utilizing the plaster of paris moulds. Handles and other complex shapes of these articles are made by casting in the plaster of paris moulds. Part of the filtered cakes is used for making slip in a cement masonry tank with the addition of required quantity of water, sodium carbonate and sodium silicate. The articles after shaping are removed to flat wooden planks for sorting, drying and handling through other sections.

For fabrication of the art wares and novelty wares, the slip casting is done with plaster of paris moulds. The casting slip is prepared by adding required quantity of water and electrolyte to the processed raw materials.

For fabricating the LT insulators, the filtered cakes are allowed to age thoroughly for uniform moisturization and developing required plasticity. Then the aged raw material is passed through de-airing pug mill for making rod shaped insulators. Other shapes of the insulators are given by using different moulds.

After the wares are fabricated and dried, they are inspected manually and given a proper finishing. If glazing is required the green articles are given a coating of glaze and kept for drying and subsequent firing in the kilns.

### *Kilns*

Firing of greens is the most energy intensive step in the process of making pottery wares. Three different types of kilns viz. downdraft kiln, shuttle kiln and tunnel kiln, are used in Khurja pottery cluster. Downdraft kilns are traditional kilns that have been used in the cluster for more than five decades. Shuttle and tunnel kilns are relatively recent entries in the cluster.

Presently around 550 downdraft kilns are in operation in the cluster. The downdraft kilns used in Khurja pottery cluster are a typical example of coal-fired natural kilns of European design. Three different sizes of downdraft kilns are commonly in use in the cluster viz. kilns of diameter 17 ft, 23 ft and 26 ft. The kiln sizes are decided based upon the desired production level. These kilns are batch type kilns. The kiln derives its name from the fact that the hot gases from the fireboxes circulate to the top of the kiln chamber, are then pulled down through the setting and leave through flue gas holes in the bottom. Under the floor, flue gas channels combine to one main flue gas path that is connected to the chimney. The specific energy consumption of the downdraft kilns is higher than that of the oil-fired kilns. Typical operation cycle from cool to cool for a downdraft kiln is about 5 days. The downdraft kilns in Khurja cluster have no monitoring equipments installed. The firing in the downdraft kilns is traditionally regulated by manually drawing sample out of the kilns from time to time and checking the samples for their properties. The investment required for setting up a downdraft kiln is around Rs 2-3 lakh that is significantly less than that required to set-up the oil fired kilns of the same capacity. Over the years the downdraft kilns have suffered from technological stagnation and there have been very little modifications/improvements made in the kiln designs.

Tunnel kilns are oil fired steady state continuous kilns. The design and technology for most of the tunnel kilns in Khurja are obtained from the tunnel kilns operating in a pottery cluster near Ahmedabad (i.e. Thangadh pottery cluster). Although the first tunnel kiln in Khurja was built in 1992, large scale adoption of this kiln took place only after 1998. Though a late entrant in the cluster, the tunnel kilns have started picking up in the cluster because of the operational advantages offered by these kilns over the conventional downdraft kilns. Presently, around 40 tunnel kilns are operating in the cluster and about the same number of kilns are under various stages of construction.

Tunnel kilns are preferred for glazed stoneware products mainly because of better energy efficiency compared to both the downdraft and the shuttle kilns. It was brought out during the discussions with KPMA that with the adoption of tunnel kilns the cost of production has come down by about 10-15% compared to the cost of production with conventional downdraft kilns. Cost savings due tunnel kilns are mainly due to improved energy efficiency of these kilns and lesser rejection rate of the finished product in the tunnel kilns. Discussion with entrepreneurs highlighted that the rejection rate with the tunnel kilns is about 2-3% compared to 10-15% of the downdraft kilns. The combined effect of all the benefits achieved by using tunnel kilns has resulted in the lowering of the prices of the finished products in the cluster. Compared to a downdraft kiln, a tunnel kiln requires more land space in order to achieve the required residence and soaking times to fire the greens. The layout of the tunnel kiln requires more length and needs a covered shed. Tunnel kilns have better instrumentation to monitor and control the operation and required skilled operators for operating the furnace.

The shuttle kilns are oil-fired kilns that are more suitable for batch production of specialized items like bone china, decorative items (stone ware), crockery (stone ware), etc. Shuttle kiln was first introduced in the Khurja pottery cluster in 1988. Presently, about 50 shuttle kilns are in operation in the Khurja cluster. In terms of energy efficiency, the shuttle kilns are not as efficient as the tunnel kilns but are more energy efficient than the conventional downdraft kilns. But as mentioned above, the shuttle kilns are more suitable alternative to the downdraft kilns for certain product categories that require large time for "soaking". The shuttle kilns are also suitable of producing bone china products as these products are light and require high biscuiting and low gloss.

In contrast to the conventional downdraft kilns, both tunnel and shuttle kilns require electrically operated blowers and fuel pumps to run the kiln.
Table 2.2 gives the advantages of oil fired shuttle and tunnel kilns over the conventional downdraft kilns.

## Fuel types

Two major types of fuels used in the Khurja pottery cluster are coal and HSD. Coal is used for firing in the downdraft kilns. Coal is made available to the pottery units in Khurja through a system of coal quota and is supplied from various collieries (e.g. eastern coal fields, etc) in India. The U.P. State Government, through DIC Bulandshahar, allocates coal quota for each unit based upon the installed production capacity. The review of the coal quota is done on a yearly basis by the DIC. The allocated coal quota is administered locally by PDO, Khurja. The pottery units in the cluster face a number of problems with regard to frequency of coal supply and the quality of coal supplied under the quota system. Most of the time the units do not receive the adequate quantity of coal allocated to them under the quota. These problems leave no option for the units but to buy additional quantity of inferior quality coal from the open market at higher costs. With the gradual phasing out of the downdraft kilns over a period of time, it is expected that the coal quota might be abolished in the cluster.

Table 2.2 Advantages and disadvantages of the oil-fired kilns over convention coal-fired downdraft kilns

| Advantages | Disadvantages |
|---|---|
| Uniform quality of fuel available compared to coal<br>Cleanliness and ease of handling<br>Ease of storage<br>Less labour required<br>Better controllability of firing process<br>Higher flame temperatures<br>Luminous flames and therefore high radiating power<br>Absence of ash and less pollution<br>Higher furnace efficiencies<br>Possibility of optimizing the operation of the kiln through automation | Higher initial investment for similar capacity oil fired kiln<br>Skilled operators required to control the operation<br>Reliable electricity supply imperative for operation |

Apart from being used as fuel for firing in the shuttle and tunnel kilns, HSD is used in DG sets and in smaller amounts to supplement coal firing in the downdraft kilns. For HSD supply, there is no administered quota for the individual units. These units buy HSD from open market. Though no testing has been done for the HSD samples, the apprehension is rife that the HSD supplied to the units is adulterated. With the gradual phasing out of downdraft kilns and adoption of oil fired tunnel kilns it is likely that the demand for oil will increase significantly over next 2-3 years.

## Infrastructure

The overall industrial infrastructure, i.e. power, roads, etc., is poor in the cluster. The poor power situation is one factor that effects the day to day operation of pottery units. Rampant and long power cuts accompanied by poor quality of power made available to the units, has forced the units to install backup DG sets. As of now, Khurja does not have a separate industrial feeder for the units.

The pottery units in Khurja receive inferior quality of power from state electricity boards. The problems related to poor power supply are:

- Rampant power failures and load shedding (without prior information)

- High voltage fluctuations
- Under voltage supply
- Voltage imbalance

All of the above factors influence the performance of motors used in raw material preparation section and shuttle/tunnel kiln operations. The performance of the motors gets effected due to all of the reasons mentioned above.

During the discussion with the entrepreneurs it was evident that the cases of motor burning were very frequent in all the units. As a result of this the production of the units suffers and due to frequent rewinding of the motors (in the local non- standard rewinding shops) the performance of motors deteriorates over time.

To check the quality of power, actual measurements were carried out where the under voltage supply was found to the extent of 15%, i.e. 353 volts was available at the usage point against rate voltage of 415 volts. The under voltage of motors reduces their operating efficiency, decreases the torque produced by motor (starting and running torque), decreases the overload capacity and increases the temperature of the motors. The effect of variation of voltage on the characteristics of the motor is given in table 2.3.

**Table 2.3** Effect of variation of voltage on the characteristics of motor

| | Voltage fluctuation | |
|---|---|---|
| **Characteristics** | 110% of rated | 90% of rated |
| **Torque** | | |
| Starting and maximum | Increase 21% | Decrease 19% |
| **Speed** | | |
| Synchronous | No change | No change |
| Full Load | Increase 1% | Decrease 1.5% |
| **Current** | | |
| No load | Increase 10-15% | Decrease 10-12% |
| Starting | Increase 10-12% | Decrease 10-12% |
| Full load | Decrease 7% | Increase 11% |
| Temperature rise | Decrease 3-4% | Increase 6-7% |
| Overload capacity | Increase 21% | Decrease 19% |
| **Efficiency** | | |
| Full load | Increase 0.5 - 1.0% | Decrease 2% |
| Power Factor | Decrease 3% | Increase 1% |

To quantify the amount of energy being wasted in the cluster due to the poor quality of power, a theoretical case study is presented here. The case study quantifies the energy loss occurring in the motors due to under voltage in supply.

## Case study

| | | |
|---|---|---|
| Operation at rated voltage (415 Volts, 3-ph) | | |
| Rating of the motor | : | 15 kW |
| Input power to the motor | : | 13 kW |
| Efficiency of motor | : | 87% |
| Percentage loading of the motor | : | 74% |
| Shaft power | : | 11 kW |
| Operation of motor at 15% under voltage | | |
| Efficiency of motor at reduced voltage | : | 0.84 |
| New input power to the motor | : | 13.46 kW |
| Increase in input power | : | 0.46 kW |
| Annual energy wastage per motor[a] | : | 3343 kWh |
| Energy loss in monetary terms[b] | : | Rs. 10700 |

Assuming that there are about 100 motors of 15 kW rating operating in Khurja pottery cluster, the total energy loss due to under voltage would be of the order of Rs. 10.7 lakh.

Since the units at Khurja, do not have proper motor protection relays, the persistent under voltage operation results in frequent burning out of motors. It is therefore recommended that the motors should at least be provided with a matching thermal overload protection relay that will prevent burning of motor windings.

Another problem faced by the units is due to under voltage. Since the motor torque reduces with reduced voltage (refer table 2.3), the units face large problems to start the high inertial loads of the ball mills.
Problems due to under voltage are compounded due to voltage imbalance and high voltage fluctuations. This results in higher temperature rise in motors and eventual burning out of motor windings. These factors further reduce the

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[a] Calculated on the basis of 24 hours a day operation for 300 days in a year.
[b] Rate of electricity Rs 3.2/kWh

operating efficiency of the motor and thus the energy loss quantified above can be actually even higher.

Since modern tunnel/shuttle kilns use electrical instrumentation, air blowers and fuel pumps, frequent power failures and poor quality of power hampers the operation of kilns. For a continuous operation tunnel kiln it is important that uninterrupted power is made available to the plant. Frequent power cuts can disturb the temperature profile inside the kiln and therefore can effect the quality of the final product. The operation of the downdraft kilns on the other hand is not dependent on power and once the kiln is fired there is no power requirement in its operation. All the pottery units in Khurja have installed DG sets to overcome the problems occurring due to poor quality of power supply. This requires additional investment in terms of up-front capital investment in hardware and recurring expenses for regular repair and maintenance of the DG sets.

Supply of better quality of power to the industries in Khurja would result in substantial economic benefits to the cluster, both in terms of energy savings and higher productivity.

In addition to above mentioned power problems, the condition of roads in the Khurja cluster is also very poor. This is big drawback to promote the cluster as a major exporting zone.

## Dynamics of innovation in the cluster

As discussed before the technological progress of the Khurja cluster can be classified in two distinct phases. In the first phase, from independence till mid 1990s, the cluster has had technological stagnation. The units operated with age-old technology using conventional downdraft kilns. For all these years, the downdraft kilns had undergone no major design changes and there was no instrumentation used in the kilns. With regard to raw material preparation and processing, the cluster has under gone a gradual change and this change has occurred more at the enterprise level. For several years now, the major equipment used in the raw material processing and preparation are fabricated locally in Khurja.

In the second time period starting from 1997 onwards, the cluster began to move towards new technology options in the form of adopting modern oil fired shuttle and tunnel kilns. Figure 2.8 shows the dynamics of technological change during this period. As shown in the figure, the major driving forces for the change over to oil fired furnaces are the competitive forces, diminishing margins and environmental regulations. During the 1990s, Khurja pottery cluster faced stiff competition from other clusters in terms of price and quality. Realizing the impending competitive pressures from domestic competitors and due to the fears of globalization, the Khurja cluster has changed its outlook for new technology options. As a response to the changing macro environment, a group of entrepreneurs from Khurja visited the Thangad pottery cluster (near Ahmedbad) in 1991 to see the operation of tunnel kilns. The Ahmedabad cluster has been successfully operating the tunnel kilns for past 10-15 years. The original design for tunnel kilns in the Ahmedabad cluster was from the U.K. After commissioning of the first plant with the U.K. design, the local technicians/ masons (i.e. *mistris*) started constructing the tunnel kilns locally in the Ahmedabad cluster. The design of the tunnel kilns was a re-adjustment and a crude modification over the U.K. design. The outcome of the first diagnostic visit to the Ahmedabad cluster did not immediately result in the large-scale adoption and diffusion of tunnel kilns in the cluster. The entrepreneurs in Khurja could still see some margins in their operations that did not call for immediate adoption of the cleaner and efficient tunnel kilns. Typical risk-averse attitude of the entrepreneurs resisted this change over.

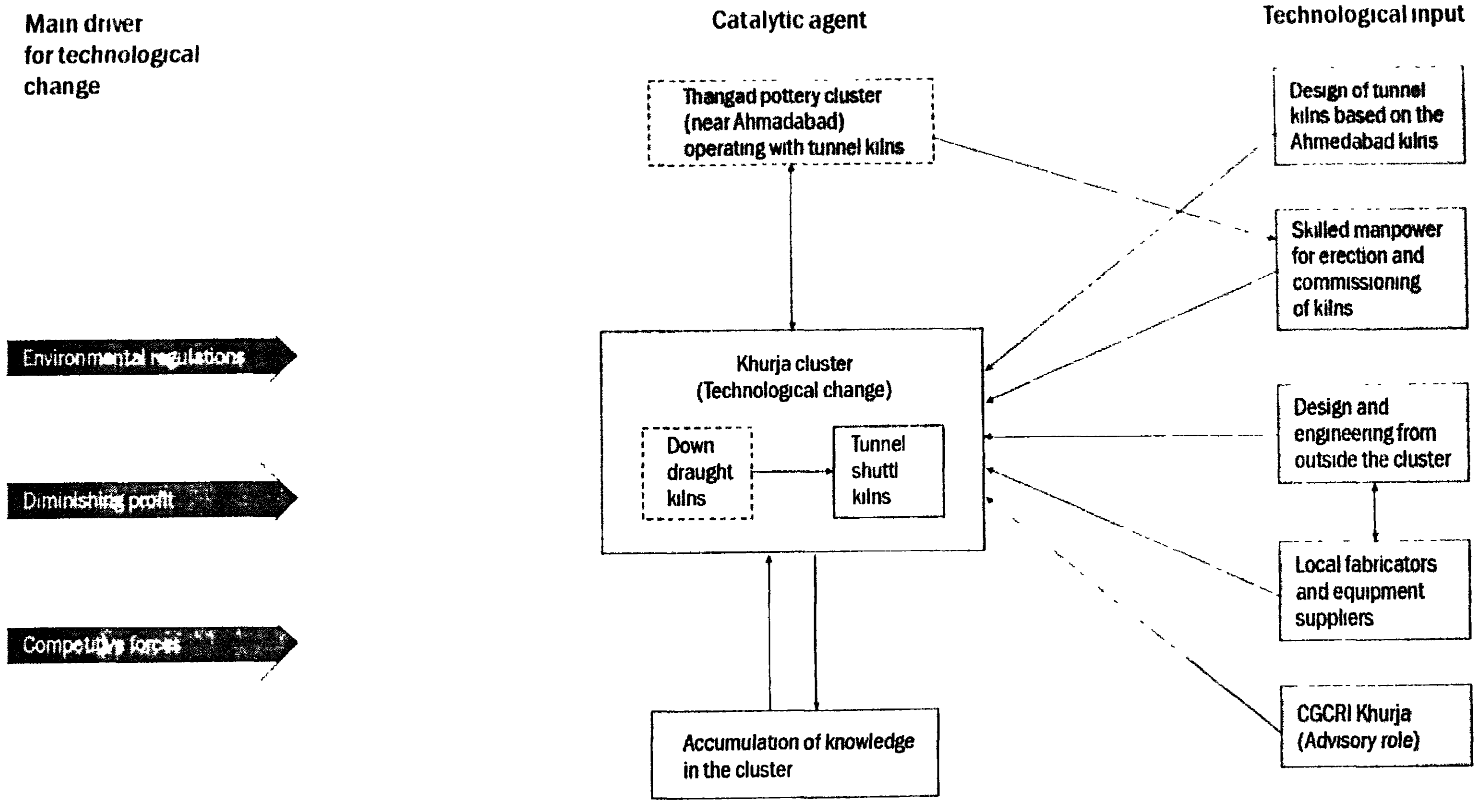
Main driver for technological change
Catalytic agent
Technological input
Environmental regulations
Diminishing profit
Competitive forces
Thangad pottery cluster (near Ahmadabad) operating with tunnel kilns
Khurja cluster (Technological change)
Down draught kilns
Tunnel shuttl kilns
Accumulation of knowledge in the cluster
Design of tunnel kilns based on the Ahmedabad kilns
Skilled manpower for erection and commissioning of kilns
Design and engineering from outside the cluster
Local fabricators and equipment suppliers
CGCRI Khurja (Advisory role)

**Figure 2.8** Dynamics of technological change in Khurja cluster

However in around 1997, two units in the cluster were issued notifications by the state pollution control board for closing their operations. This incident coupled with the competitive market forces again renewed the interest in the tunnel kilns. A team of entrepreneurs again visited the Ahmedabad cluster in 1997 and this time the local *mistris* that were involved in erection and commissioning of tunnel kilns in Ahmedabad were hired for setting up similar kilns in Khurja on larger scale. Since the construction of first few kilns in Khurja and their successful commissioning and operation, the diffusion of the tunnel kilns was rapid in the cluster. The *mistris* were responsible for complete turnkey contact for the tunnel kilns. The fabrication work was done locally at Khurja under the guidance of the *mistris*. The designs were altered without any technical justification and such changes were made purely based on the past experiences. Since many units have space limitations in Khurja, thus the design (dimensions) of the tunnel kilns was also modified so as to meet these limitations. From the discussions with entrepreneurs it was evident that their knowledge about technology is poor and that the cluster lacks experienced skilled manpower for operating tunnel/shuttle kilns.

It was also evident from the discussions with the small-scale entrepreneurs and the KPMA that all the units engaged in the production of pottery in Khurja are most likely to change over to oil fired tunnel kilns in next two to three years. The major barriers for such a change over to occur are related to finance. The small-scale units are not able arrange for proper financing through commercial banks/lending agencies because of several formal procedural requirements that these units are unable to fulfil.

## Option for using gas as fuel

The cluster has been demanding access to natural gas from the near by HBJ pipe line for over more than a decade now. The HBJ pipeline passes at a distance of 14 km from Khurja near Shikarpur. The pipeline has a provision of T-junction for supplying natural gas to Khurja. The KPMA has pursued this matter at various forums with the government for past few years. However, since the natural gas is in short supply with the GAIL and because Khurja does not fall in the prioritized Taj-Trapezium zone, the cluster has not been given natural gas until now. The use of gas in the pottery units will certainly result in better energy efficiency and improved quality of end product.

Now with the deregulation of the energy supply market in the country, it is possible to supply LPG from rechargeable bullets to the pottery units in the cluster. The entrepreneurs are very optimistic about using LPG in the tunnel kilns with some design modifications. As explained before, use of LPG will result in improved energy efficiency and better product quality. The economic viability of using LPG as fuel in the tunnel kilns depends on cost of the LPG supplied to the units. An techno-economic analysis for changing over to LPG as fuel in the tunnel kilns is presented in chapter 6 of this report.

3

# Methodology for unit selection

As a part of this project it was decided to study a few of the units in detail for evaluating their performance and determining energy conservation/process improvement options. The objective was to select a few representative units in the cluster from the point of view of the type of kiln used for firing the greens and the type of product manufactured.

To aid this, a consultative approach was undertaken by involving KPMA and CGCRI to identify the representative units. For carrying out energy audit, it was decided to focus on three units using different types of kilns viz. downdraft, shuttle and tunnel kiln and manufacturing different products. For studying the areas related to raw material preparation two additional units were also selected for detailed analysis. The list of units selected for this study is given in table 3.1.

**Table 3.1 List of units selected for detailed study**

| Name of unit | Product | Kiln type | Fuel used | Type of analysis conducted |
|---|---|---|---|---|
| Unit A | H T. and L.T insulators | Downdraft | Coal | Energy audit and raw material |
| Unit B | Crockery (stoneware) | Tunnel | HSD | Energy audit and raw material |
| Unit C | Decorative wares (stoneware) | Shuttle | HSD | Energy audit and raw material |
| Unit D | Crockery (stoneware) | Downdraft | Coal | Raw materials |
| Unit E | Bone china crockery | Shuttle | HSD | Raw materials |

## nit details

General details about the three units' which were analyzed for both kiln operation and raw material preparation is given below. More specific aspects about the kilns and the raw material preparation of each unit are covered in chapters 5 and 6.

### nit A

Unit A manufactures L.T./H.T. insulators, which are supplied to various state electricity boards and contractors. There are about 50-60 such units in the cluster and all are competing in a limited market. On the whole cluster there is no export of L.T./H.T. insulators. This unit manufactures a wide range of insulators like, pin and shackle insulators, kit-kats, etc. The installed capacity of the plant is 45 tonne per year. Unit has two coal fired downdraft kilns for firing the greens, the diameters of two kilns are respectively 17 feet and 23 feet. The capacity of the smaller kiln is 15 tonne and that of the larger kiln is 30 tonne. The total firing cycle in a kiln, from loading of green to unloading of fired products, takes about 7-8 days.

A tunnel kiln to manufacture insulators is already under construction. The unit expects to complete this project within next 5-6 months. It is expected that the rate of rejection with the tunnel kiln would reduce to about 1-2%, besides a significant energy saving of about 10-15% could be achieved in firing the products. Besides all the benefits mentioned above the unit would also get rid of the pollution problems associated with the conventional downdraft kilns.

### *Unit B*

Unit B is engaged in the production of stoneware crockery. Major products manufactured by this unit include cups, mugs, saucers, and soup bowls. The major product range belongs to the "janta" class i.e. mass consumption cheap stoneware crockery. Until the year 1999, Unit B was using two coal fired conventional downdraft kilns for firing of greens. Presently, the unit has one HSD fired tunnel kiln with an installed capacity of 2.25 tonnes per day of stoneware crockery. A second tunnel kiln has already being commissioned in this unit and is fully operational now.

### *Unit C*

This unit manufactures value added stoneware crockery and decorative wares. Unit C is mainly an indirect exporter of stoneware crockery. The main export market of its product is Germany. Because the unit manufactures decorative wares and value added crockery items, it is very quality conscious and depends on the skills of local artisans.

Until 1993, the unit was firing its products in the conventional down draft kilns. At present the unit has two oil fired shuttle kilns. The first of which was installed in the year 1993 and second tunnel kiln was constructed in 1997. Both the shuttle kilns are HSD fired and were built by proper engineering contractors from Delhi and Calcutta. For the purposes of the energy audit, the new shuttle kiln (one commissioned in 1997) was selected in consultation with the entrepreneur.

# 4

# Review of past studies for the Khurja pottery sector

The Khurja cluster suffers from low productivity, poor quality of products and limited avenues for marketing besides several other technical problems. This section reviews different reports regarding the modernization and development of Khurja pottery cluster. The objective here is to study the pervious reports and discuss the recommendations made in these reports. The review of the past studies will be useful in mapping out a strategy for the modernization of the cluster. This will also help in finding about the implementation status of various recommendations made in the cluster and to explore the reasons why some recommendations were not implemented. For evaluating the implementation status of the recommendations, a consultative approach was taken, where discussions were held with various stakeholders in the cluster. The details of various reports that are analyzed for the purposes of this study are given in the table 4.1.

**Table 4.1** Details of the past studies

| S.No. | Name of the report | Year | Conducted by |
|---|---|---|---|
| 1. | Demand Study and Industrial Profile - Development and possibilities for Pottery Industry (Pottery Industry Khurja) | 1999 | Pottery Development Office, Khurja |
| 2 | Brief survey report of Potteries, Glass Leather and Brassware (Under Technology Mission Program) | 1998 | U.P. Industrial Consultants Ltd. |
| 3 | Study of energy efficiency gaps and potential for energy conservation in small scale ceramic tableware units | 1997 | Dalal Consultants & Engineers Ltd, New Delhi |
| 4. | Basic considerations guiding improvement in productivity and quality of ceramic wares produced in the small scale sector | 1993 | CGCRI, Khurja |
| 5 | Thermal energy conservation in conventional downdraft Kilns | 1992 | CGCRI, Khurja |

Out of the reports mentioned above, the first two reports could be classified as general reports dealing with the macro environment in Khurja cluster. The third report of Dalal Consultants has given benchmark (minimum) energy consumption of ceramic units. The fourth and fifth reports, conducted by

CGCRI, are largely technical in nature. The above mentioned reports are analyzed in greater detail for their recommendations and the implementation status of various recommendations. The tables below list out the major recommendations made in all of these reports. Since all the above reports have some common recommendations, therefore these recommendations are discussed at first. An assessment of implementation status of various recommendations made in the reports is also presented. Where there was a plausible explanation of the implementation status of the recommendations or any other comment regarding the recommendations, they are mentioned in the "remarks" column.

## Common recommendations

Various common recommendations made in all the reports mentioned above are summarized below in table 4.2. Most of the recommendations discussed here relate to infrastructure, fuel supply and technology.

**Table 4.2** Common recommendations

| Recommendations | Implementation status | Remarks |
|---|---|---|
| **Infrastructure** | | |
| Availability of uninterrupted power supply to the units and upgradation of the power distribution system in Khurja | The state government has principally approved a separate industrial feeder for industries in the cluster. Once implemented this will result in: (1) no load shedding during peak hours and (2) improved quality of power (less voltage fluctuations) | This issue has been discussed at several forums by KPMA. Pottery Development Office (PDO) has also taken proactive steps to apprise government about the infrastructure related problems in the cluster. KMPA and PDO are also demanding the improvement in the power distribution infrastructure. |
| Improvement in the condition of roads and telecommunication infrastructure | Problems due to bad condition of roads still persist. | Discussion with entrepreneurs and KPMA pointed out that though Khurja comes under National Capital Region, but still it lacks these facilities. KPMA and PDO have raised this issue with the government several times. |
| Ensure regular supply of coal to the units | Not yet implemented | KPMA and PDO have discussed the problem several times with Coal India Ltd.<br>In the years to come it is very likely that coal will be replaced by HSD as fuel in the kilns. Thus, the problem will be less important in future. |

| Recommendations | Implementation status | Remarks |
|---|---|---|
| Provide export-related infrastructure at Khurja (like inland container depot (ICD), foreign exchange counters at banks, etc ) | Not implemented | The volumes of exports from the cluster are low, which are presently of the order of 4-5 containers per month. For such low volumes, it does not make economic sense to have ICD at Khurja. Moreover, since Delhi has an ICD, and because Khurja is conveniently located in its proximity, it is not pragmatic to have another ICD for Khurja. With regard to providing foreign exchange related facilities at Khurja, it should be left to market forces. If the concerned banks foresee a substantial export related business from Khurja, they will come with such provisions themselves. |
| Provide concessional finance/subsidy to the entrepreneurs for technology upgradation/modernization | Not available to the entrepreneurs | Discussion with KPMA and other entrepreneurs revealed that none of the units in Khurja had availed concessional finance. All the units have borrowed money from banks at commercial terms. |
| Supply of natural gas to the cluster | Under consideration | There is a provision of supplying natural gas to the cluster from the HBJ pipeline. The PDO and KPMA have discussed the issue several times with the government<br>The main hurdle in supplying natural gas to Khurja is the shortage of natural gas with GAIL. Presently, GAIL is unable to meet the demands of large industries (mainly fertilizer units) set up on the HBJ pipeline. |
| **Process/technology** | | |
| Promote adoption of high efficiency oil fired tunnel/shuttle kilns | Already taking place | But the change over happened not due to government initiatives but because of market forces and competitive pressure from other clusters It is expected that in next 2-3 years all the units will adopt oil fired shuttle/tunnel kilns. |

| Recommendations | Implementation status | Remarks |
|---|---|---|
| Provision to testing facilities (raw materials testing laboratories) and give technical assistance to the entrepreneurs | Already existing | The raw material testing facilities are already available with CGCRI, Khurja. Because of increased quality consciousness among the entrepreneurs, the raw material suppliers most get the raw materials tested at CGCRI, Khurja. Raw material testing has inherent quality benefits as the units have information about percentage of soda and potash in raw materials and they are also informed about the fineness of quartz and feldspar power supplied to them.<br>There is no need to establish any more raw materials testing facilities at Khurja.<br>With regard to technical assistance, CGCRI, Khurja has been providing help to the entrepreneurs in the cluster by the way of providing technological information and conducting training programs. |
| Use of modern manufacturing techniques | Not implemented | None of the reports give a detailed techno-economic evaluation for adopting the modern manufacturing techniques.<br>Most of modern manufacturing techniques are very costly and do not make sense in small-scale production. The payback for such investments would not be lucrative and will not make economic sense for the units to invest in them. |
| Encourage potters to diversify into new value added products and encourage addition of new units with improved technology in high value added category | Partially implemented | Bone china products were added into Khurja cluster in 1996. |

### *Report 1: Basic considerations guiding improvement in productivity and quality of ceramic wares produced in the small scale sector*

The above report was sponsored by Directorate of Industries, Uttar Pradesh, Kanpur, and executed by CGCRI, Khurja in 1993. It provides an assessment of the technological status in the Khurja pottery cluster and identifies major technological constraints for the upgradation of the cluster. While carrying out these studies, CGCRI had selected representative units for carrying out detailed analysis of their processes.

The study had focused on various technical aspects relating to raw material processing and operational efficiency of kilns. Though at that point of time very few tunnel/shuttle kilns were operational in the cluster, the report still has references to improving the energy efficiency of the batch type and continuous kilns. The report also recommends solutions to counter the problems related to technology, production process, fuel, etc. to improve the quality of products and the efficiency of the manufacturing process. It proposes a national support for overall improvement in the status of Khurja pottery cluster. The recommendations of this report can be broadly classified under the following heads: Standardization of raw materials, process optimization and quality control, energy conservation in existing kilns, energy conservation in new kilns, waste and waste heat utilization, and government interventions.

Table 4.3 Major recommendations and their implementation status: Report 1

| Recommendations | Implementation status | Remarks |
|---|---|---|
| **Standardization of raw materials** | | |
| Centralized procurement/purchase and/or through UPSIC | Not implemented. | Problem of consensus between the entrepreneurs for setting up a common facility as a cooperative<br>The UPSIC used to supply raw materials till 1987. UPSIC was charging higher overheads and the quality of raw materials supplied was poor. Its operations in Khurja have been closed now. This option is not feasible, as there is lack of faith |
| **Process optimization and quality control** | | |
| Setting up centralized facility for crushing non-plastic materials and/or use UPSIC facilities for this purpose | Not implemented | Same concerns as mentioned above |
| Separate grinding of non-plastic raw materials to get the required fineness | Being practiced by units | The recommendation was more valid when the units used to procure lumps of quartz and feldspar and grinding them in ball mills.<br>But now, due to economic reasons the units now procure crushed and pulverized material (quartz and feldspar), ground till 200-mesh particle size. Thus the problem of quality due to separate grinding is eliminated. |
| Use of filter press and de-airing pug mill in the raw material preparation processes | Most of the units use them in the raw material preparation. | All the units using shuttle/tunnel kilns have de-airing pug mill and filter press. |

| Recommendations | Implementation status | Remarks |
|---|---|---|
| Use of high quality dies in insulator making process | Not adopted | Presently the industry uses mild steel dies. To achieve better quality of product, high carbon steel dies should be used. But there is no market incentive for doing so. The clients do not demand such high quality.<br>Thus the recommendation does not make any economic sense. |
| **Energy conservation in existing kilns** | | |
| Optimization of firing and regulate the firing schedule | Not practiced for the downdraft kilns.<br>For tunnel and shuttle kilns it is imperative to control the firing. | Lack of simple instrumentation and improper firing method do not allow optimization of firing in the downdraft kilns.<br>Provision of simple instrumentation in the shuttle/tunnel kilns allows such control to be done manually. |
| Waste heat minimization in the kilns by improving the insulation | Implemented in 1-2 downdraft kilns.<br>Tunnel/shuttle kilns already have ceramic blanket insulation that is very efficient. | There was no techno-economic analysis carried out for the recommendation for down draft kilns. As a result the implementation was not successful in terms of its cost effectiveness. |
| egular repair and maintenance of e kilns | Practiced for all type of kilns. | |
| **ste heat and waste material ation** | | |
| the waste heat for drying of | Not implemented in any of the units. | The requirement of additional heat for drying of greens is required only for around 3-4 months in a year. This is the main reason why the investments made in waste heat recovery systems may not payback. |
| he waste fired material ss/ for manufacture of s for captive | Not used at all | Technology is yet to be developed. No foreign technology exists for this process. |
| *erventions* | | |
| dy/incentive ble financial gradation of the | Not existing in the cluster for supporting a changeover to environment friendly tunnel kilns. | No special financial and subsidy package exists for the Khurja cluster and there is no financial and institutional support from the government. |
| ementation ja | Implemented | The implementation cell exists under the PDO. |

## *Report 2: Brief survey report of potteries, glass, leather and brassware (under Technology Mission Program)*

This study was conducted under the Technology Mission Program covering various small-scale industries in Uttar Pradesh. The UPICO study concentrated on identifying problems that act as barrier to the growth and development of the pottery industry in Khurja. The UPICO report has looked at various issues related to export promotion, road, rail, power and telecommunications infrastructure. The report also looks at issues related to raw material and fuel supplies for the units at Khurja. The report however does not give techno-economic analysis of the recommendations made. Most of the recommendations given in the report are thus qualitative in nature. Various recommendations and their implementation status is given in the table 4.4 below.

**Table 4.4** Major recommendations and their implementation status: Report 2

| Recommendations | Implementation status | Remarks |
|---|---|---|
| **Process related recommendations** | | |
| Improved instrumentation in the kilns | No instrumentation exists in the conventional downdraft kilns but the new oil fired kilns have installed thermocouples to control the firing. | No interest in the cluster to provide instrumentation in the downdraft kilns. |
| Improvement in saggars through superior production methods | Not implemented | Saggers are used mostly in the downdraft kilns. But as the cluster is moving towards high efficiency tunnel/shuttle kilns, the units are less concerned about improvements in saggers. |

## *Report 3: Study of energy efficiency gaps and potential for energy conservation in small scale ceramic tableware units*

The study was conducted by Dalal Consultants & Engineers Ltd on behalf of the Office of the Development Commissioner, Small Scale Industries (DCSSI), Government of India, New Delhi). It was aimed to establish the energy conservation potential and recommend energy conservation measures. Survey, through questionnaire and discussions, were conducted by the Consultants at Khurja and Chinhat (UP) and Ahmedabad (Gujarat).

The study reveals that pottery units in Gujarat are the most energy efficient. Thermal energy accounts for about 70% of the total energy consumption and electrical energy is consumed in the slip house. Detailed energy savings and payback was recommended for measures in downdraft kiln only. Major recommendations and their implementation status are given in table 4.5.

**Table 4.5** Major recommendations and their implementation status: Report 3

| Recommendations | Implementation status | Remarks |
|---|---|---|
| Providing layer of insulation bricks on the floor of the downdraft kiln | Not implemented due to holes provided on floor of present kiln | Units not interested to make additional investment in downdraft kiln |
| Reducing radiation loss through the crown by a layer of insulation bricks | Not implemented | |
| Replacement of downdraft kiln by shuttle kiln | Many units converting to shuttle and tunnel kilns | |
| Ceramic fibre veneering of intermittent kilns | Being done in shuttle kilns | |
| Optimum loading of kilns | Done to the extent possible by the units | |
| Kiln car weight reduction | Not implemented on a large scale | |

## *Report 4: Demand study and Industrial Profile: Pottery Industry in Khurja*

This report was prepared by PDO, Khurja. It deals mainly with the infrastructure barriers for the development and upgradation of the Khurja pottery cluster. The report provides an appraisal of the present status of infrastructure (viz. power supply, roads, telecom, banking etc.) in the cluster and highlights the severity of problems due to the poor infrastructure impeding the growth of the cluster. The report also dwells upon the issue of export promotion in the cluster and the improvement of quality of products made in the cluster. On the technical side, the report mentions about adopting new technological options, but does not go into techno-economic details. Major recommendations of the above report are given in table 4.6.

**Table 4.6** Major recommendation and their implementation status: Report 4

| Recommendations | Implementation status | Remarks |
|---|---|---|
| Establishing an export promotion council (under department of foreign trade) at Khurja | Not implemented | |
| Incentives for adoption of new machines in place of traditional machines. | Not implemented | As mentioned before, the adoption of advanced machines does not make much economic sense. |
| Extended role for CGCRI in the testing of raw | Already existing. | The CGCRI, Khurja is already playing |

| Recommendations | Implementation status | Remarks |
|---|---|---|
| materials and training & development | | a proactive role in training and development of skills of local entrepreneurs. |

## Report 5: Thermal energy conservation in conventional downdraft kilns

The above study was carried out by CGCRI, Khurja and was sponsored by U.P. Government. The study had a mandate to update the technological information about the downdraft kilns and recommend solutions to various problems with the operation of kilns. This technical study focused exclusively on the performance evaluation of the conventional downdraft kilns in Khurja. The report recommends various technical measures to improve the performance of the conventional downdraft kilns. However, the report does not provide any techno-economic analysis for various recommendations made.

When the above study was carried out, down kilns were being used in large numbers in the Khurja cluster. The adoption of tunnel and shuttle kilns was at a very nascent stage at that time. But now, 8 years after the completion of this report, since most of the units are likely to change over to tunnel/shuttle kilns, the outcomes of this report lose their significance to a large extent. Table 4.7 outlines various recommendations made in the report.

Table 4.7 Major recommendations and their implementation status: Report 5

| Recommendations | Implementation status | Remarks |
|---|---|---|
| Reduction of heat loss in down draft kilns through better insulation | Implemented in one or two kilns | Use of insulating bricks, rice husk and ash mixture, Cinder and other insulating materials were recommended in the report.<br>Although the above mentioned measures were adopted in 1-2 kilns, the cost economics did not favuor wide scale adoption and diffusion. |
| Use of proper instrumentation to control the firing in the kilns and use of simple mechanization in the kilns. | Not adopted in any downdraft kilns in Khurja. | The kilns are still operated by the firemen on the basis of past experience. Since the cluster is rapidly changing over to oil-fired kilns, there is no incentive for the units to invest in modernization of downdraft kiln. |
| Improvement in the operating practices and the firing method in the kilns. | Not implemented | Still the conventional firing practices exist in Khurja. |
| Regular maintenance and cleaning of the kilns | Carried out in most of the units. | |
| Improvements in the design and construction of the kilns | Not implemented | Since late 1990s, due to several factors discussed in the report, the entrepreneurs are interested in oil-fired shuttle and tunnel kilns. Most of the capacity addition and/or replacement are coming in the form of shuttle/tunnel kilns.<br>No more new downdraft kilns are being constructed in the Khurja cluster. |

## Chapter summary

The analysis of various reports presented above shows that most of the recommendations made in the above reports are general in nature. However, the recommendations made in various reports regarding infrastructure problems in the cluster are very pertinent for achieving sustainable growth. As evident from the analysis presented above, infrastructure related problems have been highlighted for years in several reports related to Khurja pottery cluster. However, the conditions of infrastructure, power, roads, telecommunications, etc. have not improved in all these years.

None of the technical recommendations were analyzed in detail for their techno-economic benefits. Even for simple recommendations, like improving the efficiency of kilns by adopting better insulation materials, quantified figures for savings and investments are not provided. An techno-economic analysis is the first step towards getting the entrepreneurs interested in a particular technological option.

Many technical options recommended in the report were not suitable for adoption in the small-scale sector. Such options either required heavy up-front investments or were applicable for large-scale ceramic plants. For example use of advanced manufacturing technologies requires huge investments (requiring import of equipment) and are largely not applicable for small-scale industries. Although all the reports mention about the adoption of oil fired tunnel/shuttle kilns in the cluster, such a change over is already taking place mainly because of market forces.

# 5

# Problem areas and remedial measures in raw material preparation

This chapter deals with various issues related to raw material selection, procurement and processing. The objective here is to identify few appropriate technological options that result in quality improvement and/or reduced energy consumption and/or less rejections. In order to evaluate the performance of the units with regard to raw material preparation and processing and to determine various options for further improvement, CGCRI, Khurja conducted detailed analysis of five representative units in the cluster. For carrying out detailed analysis various raw materials samples were tested at CGCRI laboratory.

## present status of technology

The pottery units in Khurja face severe crises because of traditional age-old technology. These technologies and old methods of operation result in high rejection rates and poor quality of finished products (figure 5.1). These rejections have amounted to about 32 to 35% in traditional down draft kilns.

**Figure 5.1** Fired rejection in a ceramic unit using down draft kiln

Based on the major products manufactured and type of kiln, following units have been selected for the detailed study.

Table 5.1 Unit details

| Unit | Products | Kiln type |
|---|---|---|
| A | H.T. and L.T. insulators | Down draught |
| B | Stoneware crockery | Tunnel |
| C | Stoneware crockery and artistic wares | Shuttle |
| D | Stoneware crockery | Down draught |
| E | Bone china crockery | Shuttle |

## Raw material

At Khurja the major raw materials used are china clays, plastic ball clays, quartz and potash feldspars. The summarized list of raw materials is furnished in Annexure – 5.1. The physical and chemical properties of the major raw materials (collected from units A, B, C, D, & E) are given in Annexure 5.2, 5.3 & 5.4. The raw materials such as feldspar, quartz and fire clay etc., used for making of stone wares items, are generally stocked out side the premises.

There are several auxiliary raw materials and chemicals, like Marble, Soda Feldspars, Zinc Oxide, Zirconia, Barium Carbonate Chromium oxide used in these ceramics units for the preparation of glazes. Chemicals like sodium carbonate and sodium silicate are also used in the preparation of casting slip.

Plaster of Paris is another important auxiliary raw material used for making moulds. In ceramic industries, generally, beta – semihydrate plaster (type-1) is used to make moulds for fabrication of items by casting process and type 2 is used to make moulds for jiggering, cases and block making. Physical and chemical properties of plaster of paris of type-1 and type-2 are furnished below in table 5.2 and 5.3 respectively.

Frits of the opaque and transparent types are used in different types of glazes for obtaining better finish and for reducing the maturing temperature of glazes. The main raw material suppliers in Khurja are given in Annexure 5.5 and F.O.B. prices of raw materials are given in Annexure 5.6. An extensive survey of these units revealed that the raw materials are supplied by mine owners of Rajasthan, Gujarat, Madhya Pradesh, Delhi and Bihar through the local dealers and the entrepreneurs seldom feel the necessity of testing their raw materials.

Table 5.2 Physical Properties of Plaster of Paris

| Characteristic | Type - 1 | Type - 2 |
|---|---|---|
| i. Fineness | | |
| Material retained on 150 micron IS sieve, percent by mass, max. | 1.8% | 2.1% |
| Material retained on 75 micron IS sieve, percent by mass, max. | 9.2% | 5 8% |
| ii) Normal consistency | 70 to 85 | 55 to 65 |
| iii) Setting time, minutes | 20 to 25 | 20 to 40 |
| iv. Temperature rise during setting, C., min. | 10 to 12 | 10 to 12 |
| v. Modulus of Rupture, Mpa, Min. | 2.8 to 3.2 | 4 2 to 4 8 |
| vi. Dry compressive strength Mpa, min. | 7.5 to 12.7 | 10.2 to 12.2 |

(1 kg/Cm$^2$ = 100000 N/m$^2$ = 0.1 Mpa approx.)

Table 5.3 Average Chemical Properties of Plaster of Paris of Unit A & B

| Characteristic | Type - 1 | Type - 2 |
|---|---|---|
| i. Free moistures percent by mass, max. | 2.8 | 3.1 |
| ii. Carbonates (as $CaCO_3$), percent by mass, max. | 3.1 | 3.3 |
| iii. Matter insoluble in hydrochloric acid, per cent by mass, max. | 8.2 | 8.3 |
| iv. Calcium Sulfate ($CaSO_4$), percent by mass, min. | 82.5 | 81.0 |

## Processing of the raw materials

The washed China clays are generally obtained as soft lumps, which are easily dispersible in water requiring no size reduction. Bikaner clays are obtained generally in raw form but they are easily dispersed in water in the ball mill. Than clays are however hard and are not easily dispersed in water, so they are required to be disintegrated in a Disintegrator.

Unit B and D are using quartz & feldspar lumps which are broken by manual hammering up to 1" to 2" size. The units also posses all other equipments like Jaw Crusher, Ball Mill, Filter press, Blunger, Agitator, Pug mill for the processing of the raw materials. In general the units have adopted the practice of purchasing quartz and feldspar (~200 #) powder form instead of lumps. This has reduced the period of grinding in the ball mill.

The crushed raw materials (quartz & feldspar) in powder form are charged in the ball mills (Figure 5.2) along with stone pebbles and water. However it was noted that there is no definite proportion of the material charged in the ball mills. The raw materials are ground to the fineness of about 250# in the ball mill. Bikaner ball clays is also milled in the ball mill. China clays are blunged in a Blunger if required. All the ingredients are thoroughly mixed in the agitator. The ground quartz and feldspar slurry is sieved through sieve prior to addition in the agitator. The mixed slurry is then passed through a Filter Press by a diagram pump to obtain filtered cakes having moisture content in the range of 24-30%. The general composition of body mixes used by the industries is furnished in table No. 5.9. The dry & fired properties have been furnished in table 5.8.

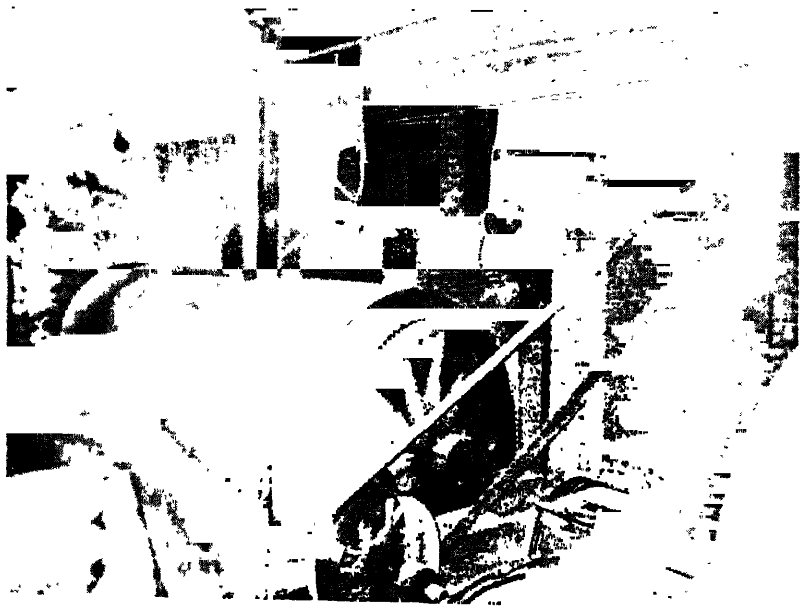

**Figure 5.2** Ball mill in one of the units

## Fabrication

### Crockery wares (Unit B, C & D)

Filtered cakes are passed through the Pug mill for homogeneous mixing of the mass and uniform moisturisation (Figure 5.3).

**Figure 5.3** De-airing pug mill

The circular shaped articles are made by Jigger-Jolly machines utilising the Plaster of Paris moulds (Figure 5.4). Handles and other complex shapes of these articles are made by casting in the plaster of paris moulds (Figure 5.5). After joining the handles with the joining slip, the joining place is brushed and the used glass bulb is moved on the mouth of the mug to make it proper in circular form (Figure 5.6). This help to prevent the warpage. A part of the filtered mass is used for making casting slip in cement - brick - tiles tank with the addition of required quantity of water and the electrolytes mainly, sodium carbonate and sodium silicate. The articles after shaping are removed to flat wooden planks for drying, finishing and handling through other sections.

**Figure 5.4**: Fabrication of Articles by Jigger – Jolly machines

Figure 5.5 Hand joining on mugs with joining slip

Figure 5.6 Brushing and rounding up

### *Art and Novelty Wares (Unit C & E)*

The non-plastic raw materials like Quartz and feldspar are finely ground in the Ball mills (~ 250#). The Plastic raw materials like China clay is also charged in the same ball mill and passed through the filter press. Required quantity of electrolyte is added for making casting slip. The properties of the casting slip are never tested at the unit for their properties. These units do not check the percentage water absorption of the slip, thereby, due to high content of water in the slip the Plaster of Paris moulds gets wet and further casting of articles become increasingly difficult.

### *Low-Tension Insulators (Unit A)*

The filtered cakes after pressing are allowed to age thoroughly for developing plasticity. Then the aged cakes are passed through pug mill for making rod-shaped insulators.

## Drying and finishing of Wares

The green wares are placed on wooden planks and are kept for natural drying inside a room or under sun drying (Figure 5.7). The summary of drying operation for different units is given in table 5.4.

**Table 5.4** Summary of the drying operation

| | A | B | C | D | E |
|---|---|---|---|---|---|
| Drying of Products | Sun drying | Sun drying | Sun drying | Sun drying | Sun drying |
| Handling losses | ~ 10% | ~5% | 2 - 3 % | Not noticed | 8-10% |
| Cracks / Warpage during drying | Yes | ~ 2-5% | 10 % | --- | Yes |
| Cracks / Warpage during handling | Yes | ~ 5 % | 2-3 % | ~ 2 % | Yes |
| Other drying method | Hot room | Setting by the Wall of the tunnel kiln | ---- | --- | Fan used with blower |

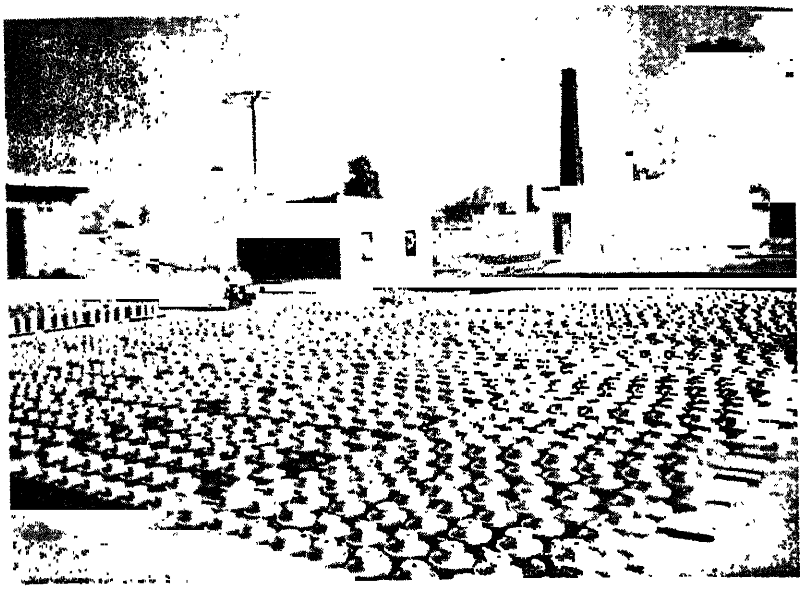

**Figure 5.7** Sun drying of greens

The time of drying depends on the size, shape thickness and the weather condition. Thick articles are generally kept for about 48 hrs inside the room before finally dried under the sun. Artificial drying is not practiced. However some units place the green wet articles on wooden planks beside the warm / hot kilns (Figure 5.8) for effective use of the hot condition. This indicates that the insulating material of the kiln walls is not up to the mark. Semi – dried flat wares like saucer bowls, soup-plates etc are kept for final drying in stacks. Dried wares are finished by removing the unwanted body mass and visual imperfections from the wares by rubbing with knives, fibres followed by wet sponging by a piece of wet cloth or sponge. The finished wares are then sorted or sent for the next operation.

The details of fabrication process are summarized in Annexure 5.7 for the different units.

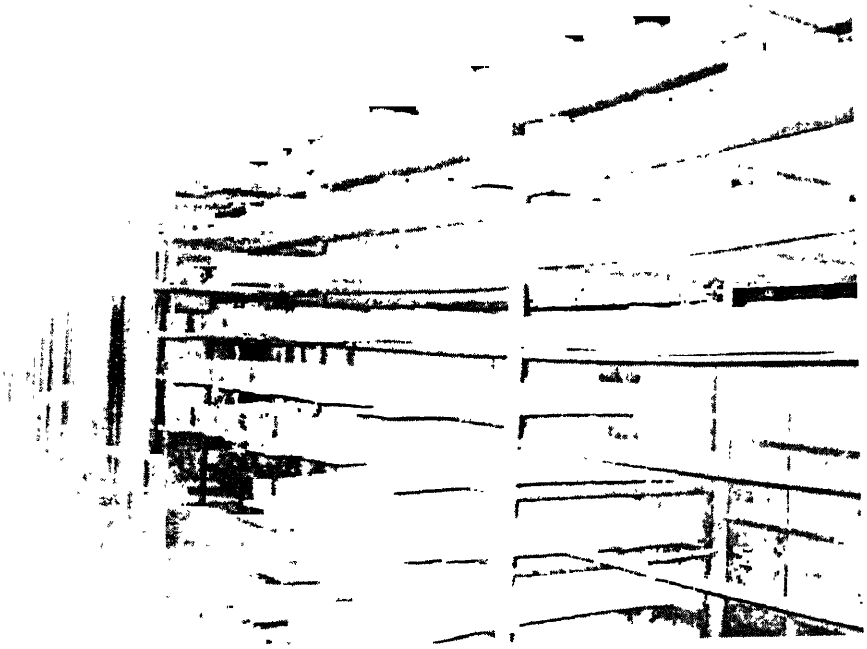

**Figure 5.8** Green wares on racks beside the kiln for drying purpose

## Glaze preparation

Potash Feldspar, Calcined quartz (1"-2" lumps), marble (1/2" lumps) Zircon and other materials are charged in the ball mill. In the first instalment containing pebbles (~ 8" size) to material ratio 1:2, water is added without measuring. The materials are finely grounded to a fineness of about 300#. Zinc Oxide, Barium Carbonate etc. and china clay are added in the second instalment in the same ball mill and allowed to mix further. The finely ground glaze is unloaded from the ball mill and passed through a small permanent magnet and then stored. The general compositions of glazes used by the units are furnished in Annexure 5.8.

## Glaze application

The prepared glaze is adjusted to a proper consistency with the addition of water. Glazing is done by dipping and pouring process (Figure 5.9). Glaze is removed from the bottom portion which will come in contact with the saggars while loading. The details of glazing operation and the composition of glazes used by different unit are given in tables 5.5 and 5.6 respectively.

**Figure 5.9** Glazing of wares by dipping & pouring process

**Table 5.5** The details of glazing operations

| Glazing | A | B | C | D | E |
|---|---|---|---|---|---|
| Firing Temp. / Soaking | 1250 to 1300oC/ 2-3 hrs. | 1225oC | 1200oc | 1210 to 1220oC | 1100oC/ 1.5-2 hrs. |
| Process of glaze application | Dipping & Pouring | Dipping & Pouring | Dipping & Pouring | Dipping & Pouring | Dipping & Pouring |
| Fineness maintained | 300# | 250# | 300# | 300# | 300# |
| Density | 1.6, 55 (Bono.) | 1.6-1.7 | 1.5 | 1.5, 45-48 (Bono.) | 1.5 - 1.6 |
| Pint wt. | No idea | 800 gm/ ½ lit. | 1.5 Kg./lit. | 1.5 Kg/lit. | 850 gm / 500 ml. |

**Table 5.6** Composition of Glazes used

| Raw Materials | A | B | C | D | E |
|---|---|---|---|---|---|
| Potash Feldspar | 53.9 | 47.0 | 48.0 | 53.3 | 50 |
| Quartz | 10.6 | 23.5 | 13.0 | 16.4 | 18.0 |
| Marble / Calcite | 11.5 | 17.5 | 13.0 | 17.4 | 15.0 |
| Barium Carbonate | 3.1 | 5.4 | 8.0 | 4.1 | 7.0 |
| Zinc Oxide | 2.4 | 5.4 | 8.0 | 2.6 | 4.0 |
| China Clay | 6.3 | 1.3 | 6.0 | 6.2 | 6.0 |
| Chromium oxide | 0.7 | -- | -- | -- | -- |
| Iron oxide | 5.8 | -- | -- | -- | -- |
| Maganese dioxide | 5.8 | -- | -- | -- | -- |
| Frit | -- | -- | 4 | -- | -- |

## Traditional skill and the labour

Khurja is well known for its traditional skill in ceramic production from ancient days. There is a vast fleet of unskilled labor available in the area as well as from adjoining areas at cheap rates. There is also availability of technical and skilled labors for different units at Khurja. The units at Khurja are generally dependent upon these labors for their production also on contract basis. Jobs are generally done on piece rate basis but the pattern of income remains more or less the same. The man power deployment at the units is summarized in table 5.7.

Table 5.7 Man power deployment

| Workers | Responsibilities |
|---|---|
| Supervisors | Supervising the works under respective sections. |
| Skilled (regular) | Grinding, body & glaze preparation, fabrication of wares, glazing & firing operations |
| Unskilled (Contract basis) | Loading of materials in ball mills, handling and conveying of articles, loading /unloading of articles to / from the kiln. |

## Quality of products

The dry and fired properties were also evaluated at different test temperatures to judge the quality stability or variation at different test temperatures (Table 5.8) and have been observed that the firing range between 1150 to 1200°C is very critical and results in wide variation of fired properties.

Table 5.8 Dry & fired properties of body mix

| Properties | Unit A | Unit B | Unit C | Unit D | Unit E |
|---|---|---|---|---|---|
| Dry Properties | | | | | |
| 1. Residue on 240 mesh sieve | 2.75 | 0.67 | 0.05 | 2.98 | Nil |
| 2 Dry shrinkage | 3.30 | 5.21 | 4.41 | 4.82 | 4.38 |
| 3. Dry Strength M.O.R. | 19.00 | 19.0 | 49 | 36.88 | 17.00 |
| 4 Water of Plasticity (Dry basis), % | 23.00 | 22.00 | 23.00 | 22.00 | 23.00 |
| 5. Particle below 10 μ % by weight | 77.0 | 72 | 80 | 88.0 | 86 |
| Fired Properties (with one hour soaking at peak temperature) | | | | | |
| 1. Linear shrinkage | | | | | |
| 1150°C | 5.04 | 5.93 | 5.59 | 3.95 | 7.06 |
| 1200°C | 7.18 | 8.73 | 6.26 | 4.93 | 9.76 |
| 1250°C | 6.26* | 9.90 | 8.69 | 6.95 | 3.62* |

| Properties | | Unit A | Unit B | Unit C | Unit D | Unit E |
|---|---|---|---|---|---|---|
| 2. Fired strength (M.O.R.), Kg/cm$^2$ | | | | | | |
| | 1150°C | 340 | 485 | 424 | 268 | 513 |
| | 1200°C | 464 | 610 | 460 | 283 | 905 |
| | 1250°C | 322* | 970 | 743 | 346 | 260* |
| 3. Water absorption, % | | | | | | |
| | 1150°C | 5.98 | 9.42 | 7.54 | 10.2 | 5.26 |
| | 1200°C | 1.62 | 2.75 | 5.05 | 7.64 | 0.00 |
| | 1250°C | 1.96* | 0.0 | 0.22 | 2.25 | 0.88* |

## Major technological problems

Basically, the production of ceramic items was started on the technology based on art and culture. But with the need of time, the pre-requisite of different objectives created the demand to provide technical inputs to the whole system of manufacturing ceramic wares. In spite of rapid progress made by the Ceramic Industries in the small-scale sector at Khurja, which constitutes about 85% of the total white ware industries in our country. Their technology is out dated and has been the subject great concern. The quality of raw materials, designs of equipment and the process technology, used here, are way behind what is used by their counter parts in the industrially advanced country. This has adversely effected the overall quality and acceptability of the product of small-scale sector, both in the domestic and the international market. For the small-scale enterprises to remain in business and thrive, substantial up gradation of their technology is required. Secondly with the limited resources of raw material etc. there is a major need of our industries to use scarce resources more efficiently, However, the problems of ceramic industries in the small-scale sector are many.

At the beginning, the cost of various inputs was very low, the productivity of different machines was also very low even then the units used to enjoy a good margin of a profit. But today, the cost of production has increased in many folds due to continuous high in the prices of major inputs like raw materials, labour and fuel. Therefore, the units at present, either incurring the losses or the margin of profit has narrowed down to such an extent that the very survival of the units has become very difficult.

Thus the major problems being faced by the ceramic units under small-scale sector may be summarised as follows under the scope of survey assigned under sub-head 5A & others in 5B.

**5A.**

- The information data base related issues
- The Raw material related issues
- Compounding of the body mixes related issues.
- The process technology and its controls related issues
- The fabrication related issues
- The drying of wares related issues
- The glaze preparation & application related issues

**5B.**

- The energy consumption related issues
- Demand potential and marketing related issues.
- Recycling and utilisation of solid waste related issues
- Finally, main power and human resource development related issues

Therefore, this Technical Need Assessment or Diagnostic survey to find out the has been carried out to find out the problems so that the technical input may be decided based on problems. As a part of survey, to identify the problems in depth, the physico-chemical properties of raw materials, the different parameters of processing of body mix, the different parameters of fabrication systems etc were studied. Based on those parameters and discussions with the entrepreneurs, the following problems can be summarized:

## *e information database related issues*

The survey revealed that there is a total lack of information database regarding the properties and functions of different raw materials and the products manufactured by them. They are generally dependent on the skilled workers & supervisors. Who actually carry out their production based on age-old knowledge of raw materials & production systems of different labour scenario. But are unaware of modern techniques of production and management. This lack of information database is mainly technological communication gap and broadly can also be out lined as technical audit.

- Lack of information about cost effective production techniques & new equipment/ machinery.

- Lack of information about cost effectiveness of products (production & market scenario).
- Communication gap regarding technological up gradation & market demand.
- Lack of information of conventional raw – materials – their availability in Indian and foreign scenario with their chemical constituents & physical properties and their functional effects.
- Lack of information of alternate non-conventional raw-materials – their physical properties chemical constituents and their functional effects.
- Inadequate trained human personals.

Resulting slow development in technology.

### *The raw materials related issues (Unit ABCD&E)*

Basically, the traditional bodies are made of bodies often divided in to triaxial bodies – containing predominantly the components – clays, quartz and feldspar etc. and non triaxial bodies – containing substantial amount of non conventional materials. These raw material are the main responsible factor for the quality any products, though they are available in plenty in our country but have the following major draw back:

- Sub-standard quality of raw-materials
- Irregular supply of standard quality
- Consistency in the composition of the Raw materials
- Low green strength of china clay
- Variation in the moisture content of china clays/ball clays.
- Variation in the Particle Size and particle size distribution of ground non-plastic materials and clays.

To control on these draw backs, at first, it is essential to evaluate the properties of the raw materials which has been furnished in Annexure – 5.1, 5.2 and 5.3.

These above draw-backs reduces the whiteness of the products, workability and reproducibility of products.

## Compounding of the body mixes related issues (Units ABCD & E)

Ceramic bodies are always compounded in accordance with their required properties. Basically, Tri-axial Body compositions are used for compounding the body mix in the Units under survey. Through slight variation is being carried out to get the required properties of individual unit. The composition of body-mixes of different units is given in table 5.9.

Table 5.9 Composition of body-mixes of different units

| Raw materials | Unit A | Unit B | Unit C | Unit D | Unit E |
|---|---|---|---|---|---|
| **A. Non-plastic material** | 51.89 | 45 | 58.9 | 53.4 | 60.2 |
| 1. Quartz/silica sand | 26.42 | 26 | 9.8 | 26.7 | - |
| 2. Potash feldspar | 25.47 | 19 | 39.3 | 26.7 | 12.5 |
| 3. Pyrophylolitic | - | - | 9.8 | - | - |
| 4. Bone Ash | - | - | - | - | 47.5 |
| **B. Semi-plastic clay** | 33.96 | 29 | 20.5 | 10 | 39.77 |
| 1. Bhuj clay | - | 11 | - | - | - |
| 2. Amrapali china clay | - | 11 | 20.5 | - | - |
| 3. Ashwin china clay | 19.81 | - | - | - | - |
| 4. Rajmahal china | - | 7 | - | 10 | - |
| 5. English India china clay | 14.15 | - | - | - | 11.36 |
| 6. T.T.-75 | - | - | - | - | 9.09 |
| 7. Rajmahal china clay (white) | - | - | - | - | 19.32 |
| **C. Plastic clay** | 14.15 | 26 | 20.5 | 36.7 | - |
| 1. Bikaner clay | 9.43 | 17 | - | 10 | - |
| 2. Bikaner ball clay (pink) | - | - | 20.5 | 20 | - |
| 3. Than clay | 4.72 | 9 | - | 6.7 | - |

Though the higher percentage of ball clay (at an average of 24%) is used to increase the green strength of body mix to facilitate the workability in fabrication, but it results higher green shrinkage resulting higher green rejection etc. this use of ball clay also results in reducing the whiteness of the body mix. Therefore, the major problems due to compounding are as follows:

- Low firing range (1190 ~ 1210°C)
- Low green strength
- Higher green rejection
- Poor surface finish mainly due to pin holes and rough surface.
- Warpage etc.
- Low whiteness of products

These major problems results higher green rejection around 5 to 8% in fabrication & drying.

## *Processing and controls related issues*

Due to lack of knowledge of processing parameters, the entrepreneurs of Khurja operate their units in a traditional manner without enforcing modern process control measures, effecting directly the following parameters:

### Size reduction/Grinding

Variation in particle size and particle size distribution occurs due to:

- Defective proportion of stone material, water and pebbles for grinding.
- High or low speed of the ball mill.
- Large size of feed material.
- Variation in shape and size of pebbles.
- Frequent fluctuation in power supply and cut.
- Electric motor of low capacity.
- Density of grinding media.

Resulting in higher production around of 2nd quality and low vitrification.

### Pug Milling

- In homogeneous moisture content causes shrinkage variation & cracks.
- Development of stress & strain due to torsional movement of the plastic mass in side the pug mill resulting cracks etc.
- Entrapped air in plastic mass develops cracks during firing or leaving pinholes and blisters during application of glaze or firing.
- Too hard or too soft plastic mass due to defective pugging.
- Motor of low capacity causes inadequate de-airing of plastic mass.

Resulting low workability & green rejection around 1%.

## *Fabrication related issues (units ABCD&E)*

The circular shaped articles are fabricated by jigger-jolly machine using Plaster of Paris mould and complicated shapes are made by slip casting using plaster moulds. The unit A, manufacturing the electrical LT & HT Insulator, the pressing is used to shape the items. The main problem arises during both processes (Jigger-Jolly & Slip casting) are furnished below:

## Shaping of article by Jigger – Jolly

- Warpage
- Cracks
- Sticking with the mould
- Variation in the compactness due to variation in speed of Jigger Jolly, eccentricity in Jigger head etc.
- Surface of the moulds resulting rough surface defects

Resulting green rejection of about 5% though the plastic mass is recycled but leads to labour loss & low productivity.

## Shaping of articles by Slip Casting

- More casting time
- Difficulties in draining.
- More hardening time
- Flabby mass
- Development of cracks in the articles inside the mould
- Development of cracks after removing from mould.
- Development of pin holes
- Rough outer surface
- Difficulties during releasing of articles from moulds
- More thickness in bottom.
- High thixotropy slip which affects casting properties.

Resulting higher rejection around 7% and above especially in green stage.

## Drying of wares related issues

For drying the units generally depends upon the weather condition. India being tropical country, drying arrangement in rainy season for heavy articles like H.T. & L. T. insulators only. Generally entrepreneurs of Khurja have adopted natural drying utilizing sunlight for drying purpose as well as waste heat near by Kiln walls Shuttle & tunnel kilns, where lot of heat energy is radiated. Though, the first Mangle drier is under construction at M/s Shankar Ceramics, Khurja. The natural drying, having no. of Variable parameters results heavy rejection due to drying cracks etc.

### Glaze preparation & application related issues

Generally, the glaze is composed using raw materials VIZ quartz, feldspar, clay, zinc oxide, barium carbonate etc. in the raw-glaze form. (as furnished on page no. 21). Which is ground in ball mill. For fine grinding (-300 mesh size) adequate time about 35 – 40 hours is being given for grinding. But due to lack of knowledge of using scientific/technical parameters, the entrepreneurs of Khurja are grinding the glaze in ball mill for about 100 hours to get – 300 mesh fine fractions. The following problems generally are prominent in the sub glaze formulation especially $Al_2O_3$, $SiO_2$ ratio and % of fluxing constituents.

- Substrate – porosity and surface texture depending upon the particle size distribution and consistency.
- Application technique due to adaptation of traditional dipping systems, being easy and high adaptability of this low cost system.
- Higher firing temperature for raw glaze.
- Thixotropy behaviour of glaze lowers the draining characteristics.
- Thin coating and rough surface.
- Pin holes in glaze coating (dry state)
- Cracks development in glaze coating (just after glazing).
- Spots are to red mud particles or iron etc.

Resulting high cost of production and higher percentage of 2nd quality products around 20%.

## Remedial measures for diagnosed problems

Undoubtedly, the market is a basic factor of the success of any industry but when it reaches to saturated state as in case of traditional ceramic in developed countries and at Khurja, we can conclude that the competivity in this sector can no longer be co related to produce more but rather must be co-related to the quality of finished products and the management of the production process. Thus in Khurja scenario, at present, producing more to reduce the cost per unit produced is no longer is a valid concept, the production has been optimise to the maximum possible with available facilities and market scenario though with higher rejection. It is, therefore, now necessary to produce "better" i.e. to achieve greater yield of first class products so to decrease the relative contributions in the cost analysis. Which can be materialised by the technological development for cost effective and qualitative production of zero defects. This cost effective in qualitative requires to include the remedial measure in our input - production system output cycle etc.

This section describes possible remedial measures for problems discussed above. Techno-economic analyses is also carried out and is provided wherever applicable.

## *Information database related issues*

Due to lack of knowledge regarding raw materials and their functions in the body as per composition, different types of problems are observed which direct affects on techno-economics due to loss around 10% and above.

- Information gap may be fulfilled by providing Training programme at CGCRI and visiting different International Trade fair for ceramic machinery time to time.
- The information about cost effective products can be availed / achieved through different workshop/seminar and National & International market survey.
- To reduce communication gap for technological up gradation and market demand special T & D Programme and short term marketing management courses should be organised by well reputed organisations.
- To provide infrastructures for testing of physical properties and chemical analysis for the entrepreneurs of Koura.
- Time to time training programmes and imparts knowledge of raw materials and their functional effects.
- Alternate non-conventional raw material is selected on the basis of their physico-chemical properties as well as their cost. In addition to the above Information for alternate non-conventional raw materials like low grade fire and ball clays should be collected from different local mining offices and their ceramic properties and their effect in the body mixes should be tested as to be checked as per Annexure 5.9.
- The most of the pottery units are in the habit to develop their supervisory and technical personnel from low educated level. They should selected qualified technical / supervisory staff and they should be deputed for different training programme to up grade technological status CGCRI conducts different training programme for technological up gradation.

## *Raw materials related issues*

Every raw material has its own function and the properties of the ultimate product depend upon the relative proportion of the constituents and if the presence of any impurities is not rectified. It is difficult to give qualitative production.

As discussed in chapter 3 item no. 3.3 regarding raw-materials related issues, we can summarize the remedies as follows:

## *Sub-Standard quality of raw-materials*

- Upgradation of mining industries is required but this may be a long term measure.
- The supply of quality raw material is not maintained by the suppliers. It is therefore suggested that each lot of the raw material should be tested regularly.
- Generally, the composition of raw materials are changed layer to layer and also in the same layer in the mine. Therefore, the blended raw material of same type should be supplied for use in production so that consistency in the chemical composition of raw material can be maintained at production level. Each lot of material should be tested before use to maintain the same.
- Blending of clay materials in large quantity should be carried out at mine or by the user to improve the green strength before incorporating in to the body mix. After blending material is to be aged to improve the plasticity as well as strength. The best quality ball clays can be used to improve the quality.
- Moisture content in the china clay & ball clay should be tested during delivery to adjust the cost of material and during use to adjust the body composition. (details of losses furnished as below :
- Particle size and particle size distribution of ground non-plastic materials and clays should be tested for each lot at plant as it will enhance the plasticity of body-mix.

## *Moisture content*

- Low Green/Dry strength of ball clay

### (i) Moisture Content

If acceptable amount of moisture content in the clay is 2% and mine owner delivers the clay with 7% moisture, the losses due to excess amount of water will be around Rs.175.00 per ton (assuming the cost of china clay @ Rs. 3500.00 per ton.

If, an entrepreneurs uses about 200 tons of clay in a year with 7% moisture and acceptable moisture is upto 2% then loss will be Rs.35000/- in a year.

The above also influences on body composition, therefore, it is essential to determine moisture content and adjust the composition to save further loss.

### (ii) Low Green / Dry Strength of Ball clays

The green articles are broken easily during handling, finishing, glazing and loading for firing.

This is due to low plasticity and dry strength of Indian ball clays. To prevent loss due to breakage, high amount of plastic clay above 15% is generally use. Even then about 10% losses of green ware observed during handling, finishing, glazing and loading for firing. If good quality of ball clay (Imported) is used in place of Indian ball clay the rejection loss may be reduced to 2%. But the cost of body will be more. If blended clay of improved plasticity and dry strength is provided to the entrepreneurs, the rejection in greens may be reduced 10% to 4%. Hence, the total profit can be calculated as below:

If cost of green product @ 8000/ MT and production is 2 MT per day then total loss will be;

$$= \frac{2 \times 300 \times 8000 \times 10}{100} \quad \text{[300 days in a year]}$$

$$= \text{Rs } 480000 \text{ /year}$$

If good quality clay / ball clay / blended clay is used the loss can be reduced to 4% then total loss will be;

$$= \frac{2 \times 300 \times 8000 \times 4}{100} = 1{,}92{,}000/-$$

Hence, profit after using high strength, good quality ball clay will be

$$= \text{Rs.}4.80 - 1.92 = 2.88 \text{ Lakhs}$$

At least 50 industries at Khurja having the above capacity to produce crockery and insulators. Therefore total profit may increase to 2,88 X 50 = 144.0 Lakhs.

## Non – availability of Plastic ball clay

It has been observed that there is heavy rejection of green wares due to Low green strength, high green shrinkage etc. during handling, finishing glazing and loading etc. Which is mainly due to:

- Low plasticity of Indians ball clays
- Using higher percentage of Ball Clay (> 5%) in body mix.

It is, therefore, suggested that utilization of highly plastic clay (~ 5%) but keeping the optimum required plasticity, will allow to include higher percentage of semi-plastic china clays. Which ultimate reduces dry shrinkage from ~ 5 to 3% and more whiteness in the fired products thus finally controls the rejection

## *Cost Benefit analysis*

As per survey, it has been observed that the Ball clay is used at an average of 24.33% (Table 5.9) due to its low plasticity. Though it is low cost but imparts cream colour to product, therefore it is not advised to use more than 6% in the body mix. Assuming the production capacity of a Unit of 2 Tones / day and the price of imported ball clay around Rs.18000/- per ton.

### Financial Involvement for improved system

| | | |
|---|---|---|
| Annual requirement of Imported Ball clay | = | 36 Tons |
| Cost of Imported Ball clay | = | Rs 6.48 Lakhs |
| Cost of presently used ball clay of low plasticity @ Rs.1500.00 per ton for 24.33% = 145.98 Tones | = | Rs 2.19 Lakhs |
| Excess financial involvement required | = | Rs 4.29 Lakhs |

### Pay back period

A.1. Rejections due to visible cracks during drying mainly because of high drying shrinkage of body mix and improper drying, it have been estimated about 10% in the case of Insulators & 4% in table wares. Taking the lower rejection of the fired products only (as the green rejection is recycled to make the body-mix. Thus we can assume to reduce the fired rejection at least by 1.5% of the production which can be calculated as:

- 1.5 % of production of 600 Tones/year - 9 ton
- Cost benefit @ Rs. 20.00 per Kg. Rs. 1.90 Lakhs

A.2 The use of higher percentage of low plastic ball clay (~24.33%) instead of using 6% imported highly plastic ball clay will results in higher warpage due to high drying shrinkage around 7 to 8%. Using low percentage of high plastic ball clay we can reduce the product of 2nd quality from 25% to 15% (saving of 10% in 2nd quality). Existing average gradation of the final products in different units is given in table 5.10.

Table 5.10 Average gradation of the finished products

| Grade | % Age | Price Rs./ Kg (120 gm / pc | Price Rs./ pc. |
|---|---|---|---|
| 1st Quality (400 No) | 5% | 20.00 | 2.50 |
| Commercial quality (300 No) | | | |
| 2nd quality | 65% | 16.00 | 2.00 |
| 3rd quality (200 No) ( mostly having Warped mouth) | 25% | 12.00 | 1.50 |
| Rejection (not saleable) | 5% | --- | --- |

Price benefit of Rs 4.00 per kg for 60 tons = Rs 2.40 Lakhs

A.3. By using good quality imported ball clay, we can increase the proportion of semi plastic china clays to improve the whiteness of products. Taking the factor of whiteness only, we will able to increase the percentage of 1st quality from 5 to 25% and reduce the 2nd quality from 25 to 8% (10% already accounted in A.2., therefore accounting only 7%).

Price benefit due to increase in 1st quality by = Rs 4.80 Lakhs
20% of 600 Tons @ Rs. 40.0 per kg.

Thus, the factors as mentioned above (A.1, A.2 and A.3) will result in payback of Rs 9.10 lakhs against the excess expenditure of Rs 4.29 lakhs.

## *Compounding of body mixes related issues*

The ceramic bodies are always compounded in accordance with the required properties. Which depends on mineralogical and chemical composition. Secondly, on structural factors namely micro – and macro – structure, homogeneity and porosity etc. for which following precautions are essential:

- Regular supply of Raw-materials of similar composition
- Using best quality plastic ball clays to reduce green rejection by improving green / dry strength.

- By controlling particle size & particle size distribution of body mix and use of best quality Plaster of Paris moulds.
- Warpage in green stage can be minimized using plastic mass of moderate plasticity as well as uniform pressure during fabrication of articles by jiggering. More attention is required for placing of green ware after removing from mould as well as during handle before leather hard. Drying of articles showed is slow.
- Controlling other structural factors by technological processes e.g. ball milling etc.
- Widening the firing range to accommodate the temperature differences at top and bottom of the kiln at the same profile.

## *Process technology and its controls related issues*

### Size Reduction / Grinding

The evaluation of particle size distribution of body-mixes was carried out as furnished in table 5.11 and it has been observed that the fineness of the grinded body mixes are not to the standard specification and require technological intervention.

**Table 5.11** Particle size distribution of different body mixes

| | Unit A | Unit B | Unit C | Unit D | Unit E | Standard Specifications |
|---|---|---|---|---|---|---|
| Below 1 μ | 26 | 36 | 31.0 | 15 | 35 | |
| Below 2 μ | 40 | 44 | 42.5 | 35 | 50 | |
| Below 10 μ | 77 | 72 | 80 | 60 | 80 | |
| Residue on 200# | 2.75 | 0.67% | 0.05 | 1% | Nil | |
| Residue on 300# | 4.50% | 3.8% | 13.6 | 13% | 0.63 | 0.63 |

It was clearly an example of technological gap when it was opened by the entrepreneurs that we increase the time of grinding to improve the grinding. This is on the contrary technically wrong in their cases, when grinding media is soft, the grinding media also get pulverised and the ratio of pulverised grinding media starts increasing in the body mix with increase in firing temperature.

Due to lack of knowledge, entrepreneurs of Khurja do not care more on process. It is very important section by which quality can be improved markedly. In this section, grinding of raw material or body is an important process to reduce the particle size in to less than 300 mesh fractions. The fine particles are easily reacted during firing and produce better microstructure at lower temperature compare to the body of coarser particles. It produces smooth surface as well as improves fired strength.

To improve the grinding efficiency, there should be correct proportion of materials, water & in the pebbles in the ball mill. The recommended proportion of materials is given in table 5.12.

**Table 5.12** Recommended proportion of materials in the ball mills

| Material | Amount in parts | % by weight |
|---|---|---|
| 1. Quartz and Potash feldspar<br>( below ½" size) | 1 part | ~ 28 % |
| 2. Pebbles (Assorted) | 1 to 1.5 parts | ~ 42 % |
| 3. Water (Soft) | 0.5 to 0.6 parts of materials | ~ 16 % |

The recommended speed for efficient grinding is given in table 5.13.

**Table 5.13** Recommended speed of ball mill

| Diameter of ball mill | RPM |
|---|---|
| 1' | 65-70 |
| 2' | 45-50 |
| 3' | 35-40 |
| 4' | 29-33 |
| 5' | 23-25 |
| 6' | 20-25 |
| 7' | 17-20 |

- Feed material below ½" ( if gritty material is fed)
- Size of pebbles should be considered as per the specification mentioned in Annexure 5.8.
- Shape of the pebbles should be spherical or cylindrical.
- Make arrangement to provide continuous operation of ball mill & routation measuring device
- Motor should be used of required capacity.
- Density of grinding media should be more than 3.4 i.e., high alumina balls, zircon grinding media etc. (Annexure 5.8).

It is, therefore, suggested that specific grinding media viz. High alumina, zircon grinding at media etc should be used instead of inferior quality and easily available grinding media. The bulk density of high alumina grinding media (3.6

gm/cm3) in comparison to Ganga pebbles (2.5 gm/cm3) is being higher. The impact force is always more to result better grinding. Which results in time reduction of grinding. This is very essential in the present scenario of irregular power supply with low voltage. Secondly, the contact area between the pebbles also play very important role in fine grinding. The water used for grinding of materials is not generally measured and added approximately just by idea. So, some times, the grinding is ineffective due to low and high quantity of water. Low quantity of water stops the movement of balls and materials inside the ball causes no grinding. High quantity of water, make the low viscosity paste, causes less contact of material with balls and therefore low grinding. Hence, with the implementation of measuring instrument for water, this problem can be minimised in all the pottery industries.

For calculating the payback period for the technological intervention, we may assume the following parameters for high Alumina grinding media.

- Percentage of alumina 85 to 90% in comparison to 26-30% of Alumina in grinding media manufactured at Khurja and high silica in Ganga pebbles
- Price of high alumina grinding media Rs.100/- Kg while the average price of grinding media (Ganga pebbles) at Khurja is Rs.1/- Kg, Agate Rs. 30/- Kg, Rs.15/- kg for low fired porcelain pebbles.
- As per standard weight ratio of raw-material and pebbles of 1:1.4 (2100 Kg : 3000 Kg)
- Production of 16500 pcs of green mugs for 2 tonnes/day capacity consumption and Rs.1.8 per kg of green body-mix.

While calculating the resulting parameters during grinding in present and suggested scenario, the following observations may be summarised (table 5.14).

Table 5.14 Parameters during grinding - present and suggested scenario

| | Traditional (Ganga Pebbles) | Improved (Suggested Pebbles) |
|---|---|---|
| Loss of weight of pebbles during grinding per 100 hrs. (~ 5 days) ( % basis) | 15 % | 1 % |
| Saving in green rejection during shaping due to increase in green strength etc by proper grinding (4% of 16500 pcs/day production) for 5 days (i.e. 3300 pcs.) | --- | Rs.82.50 |
| Rejection in fired products because of low chipping and fired strength due to improper particle size distribution in the body-mix during sorting, packing and transit to market @ 1.5% difference during five days production | ---- | Rs. 1650.00 |

| | Traditional (Ganga Pebbles) | Improved (Suggested Pebbles) |
|---|---|---|
| Time and energy saving due to suggested cylindrical shape of high alumina grinding media in comparison to irregular round or flat shaped Ganga pebbles in turn of production, electrical energy assuming @ of Rs. 0.20/- Kg of saving in the present processing cost of body mix of Rs.1.80/- kg for 5 days production. | | Rs. 2000.00 |
| Reduction on maintenance cost due to wear and tear of machines for grinding @ 20% of maintenance (5% of total plant & machinery around Rs. 20.00 lakhs) | | Rs. 333.00 |
| Pay back of 5 days (A.1,A2, A.3, A.4) | Nil | Rs. 4065.00 |
| Less cost of refilling after an operation of 5 days (100 hrs. ) for 1 ton of grinding media | Rs.150.00 | Rs. 1000.00 |
| Balance in Profit | Rs.150.00 | Rs. 3065.00 |

It is needless to mention here that the quality up gradation of products will also help to increase the market goodwill and potentiality.

## Pug Milling

Use appropriate pug mill to mix body uniformly

- Auger of pug mill should be rectified to remove the stress & stain in side the plastic mass.
- Use de-airing system in pug mill.
- Control moisture content during filtration by pressure gauge fitted with filter press.
- Use Electric motor of required capacity.

## Shaping of articles by Jigger – Jolly

- Change defective moulds & precaution during removing the article from mould as well as on adherence with the mould.
- Unequal pressure with profile on the layer of articles as well as adherence of a part of article with Plaster of Paris mould. Caused cracks therefore the same may be rectified with appropriate techniques. Use 10 mm thick steel flat for profile making.
- Use water as minimum as possible during final touching of article during fabrication in the mould.
- Adjust plasticity of body mix.
- Adjust the profile in Jolly.
- Remove the damaged, long used or defective Plaster of Paris mould. Use better quality of Plaster of Paris for making mould which should be prepared using 100 parts of Plaster of Paris and 78 parts of water.

## Shaping of article by casting

- Control density of slip 1.60 – 1.65 gm / Cm3
- Use electrolyte in slip to make adequate fluidity with required density.
- Use Sodium carbonate solution as required for slip which helps for proper hardening
- Use clays containing minimum free calcium carbonates.
- Make slip with required amount of water and electrolyte. Use plastic material as per required by the body. Remove moulds of high porosity
- Remove articles from mould with soft handling and place it on plane surface.
- Make slip free from air bubbles. For this use appropriate amount of electrolytes and water.
- Remove the old / defected moulds & use well finished mould.
- Remove defective mould or make mould in parts as per design. Make moulds using 100 parts of Plaster of Paris and 90 parts of water.
- Control water in the slip. Check grinding and control particle Size distribution of body mix.
- Use electrolyte in actual quantity. Remove clays containing high amount of free Calcium and magnesium carbonate from body composition during formation. For making casting slip, use clay after proper testing of free calcium / magnesium carbonate present in the clays.

Utilization of high strength Plaster of Paris is a common remedies for both the above mentioned process of fabrication.

Though the recent advancements in calcinations kilns from wood-fired updraft kiln to oil fired Rotary kiln during the last few years, has improved the quality, but not to the present required standards as compared to that available abroad in general. Therefore, it is suggested to use better quality (may be imported) of average price Rs.25/- per Kg. This will reduce the requirement of moulds for fabrication, being of longer life of operation. Secondly, it will also improve the surface finish to upgrade the quality and in term available cost. Keeping in view the present fabrication of 2500 pcs/day with 500 moulds, it is estimated that using better quality Plaster of Paris (~Rs. 25/- per kg) in comparison to presently used (~Rs.4/- per kg.) with increase in the cycle of operation for the number of Plaster of Paris moulds to be doubled but with an increase in the expenditure of Rs.0.67 lakhs/year.

The payback analysis may include the following returns (not included in previous estimation).

A.1. Increase in surface finish, which will ultimately result in the increase of commercial quality and reduction in 2nd quality products. If we take the products having pitting due to rough surface of moulds. It can be estimated to increase the percentage of commercial quality by 2.5% per 2nd quality, the resulting up gradation of value will be Rs. 0.60 lakhs.

A.2 By using high strength Plaster of Paris, we can fabricate the table wares of better surface finish which will reduce the labour of dry finishing and can be estimated to Rs.0.18 lakhs ( Rs.60.00 per Kg.)

Therefore, we can estimate the payback of Rs.0.78 lakhs as against excess expenditure of Rs.0.67 lakhs per year.

### *Drying*

Arrangement for drying is required in large scale production as well as for heavy articles. For this purpose waste flue heat can be used by constructing tunnel dryers or hot room.

### *Glaze preparation*

Problems arised during glaze preparation can be removed by controlling the followings:

- Alumina Silica ratio
- The glaze material should be ground properly to make the surface texture smoothly for this, use assorted size of pebbles of required density during grinding of glaze materials using equal amount of water.
- The system for glazing at Khurja is very easy, this is because of low cost system.
- Use materials & chemicals after proper testing of chemical constituents.
- Raw glaze require more energy for maturing at a particular temperature therefore fritted glaze can be used to reduce the temperature and improve the glaze surface.
- Adjust density of glaze slip by controlling amount of water as well as electrolytes.
- Use appropriate amount of electrolytes.

- Increase density of slip check fineness and if required, again grind.
- Remove air bubbles from glaze slip by adjusting fluidity, amount of water & electrolytes. If required left the same on vibration table.
- Increase plastic clay or binder etc.

## Utilization of Fritted Glazes

The type of glaze formulation for various types of substract are complex and in turn, the glaze properties is affected by the individual constituents. For example the fusion characteristics of a glaze with the same chemical composition, but one fully fritted requires less energy and vitrifies more quickly than the other totally raw system (as shown in Figure 5.10).

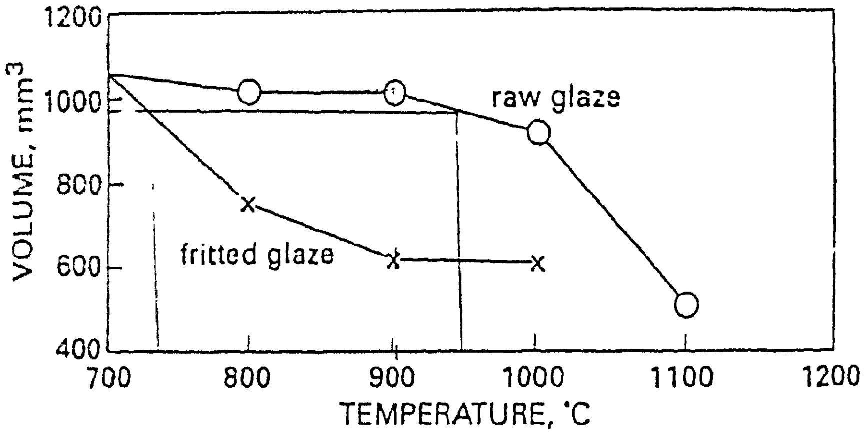

**Figure 5.10** Fusion behaviour of raw and fritted glazes

The importance can also be visualized from the fact, that the raw glaze, which was used when the products were fired to D.D. kiln (where the firing time is about 30 hrs.) can not be sintered (melted) on the surface of green products within 12 hrs in shuttle kiln or in tunnel kiln to get the same glassy finish. Apart from energy saving in melting, the glaze on the surface of green product in case of fritted glaze in comparison to raw glaze helps to minimize the pinholes (the present major defect in Khurja industries). As the fritted glazes are composed for controlled surface tension.

The particle size distribution also has an influence on the resultant fired appearance and glaze manufacturers are investigating the feasibility of alternative grinding techniques and conditions so as to alter the distribution of the particles towards a reduction in the coarse fraction without increase in the super fine fraction.

However, the requirement of fritted glaze to produce 600 tonnes/year of products will be 48 tonnes (@ 8% of finished products) i.e. worth Rs.9.6 lakhs while of the raw glaze will be 72 tons (@ 12% of finished products) Worth Rs.7.2 lakhs thus the technology implementation will require the additional input of Rs. 2.4 Lakhs.

As mentioned above the fritted glaze will require low energy consumption and will minimize the defects like pinholes, surface finish etc. which are the need of this highly competitive scenario in India & abroad.

- Assuming the 2% increase in quality of product in respect of surface finish & pinholes etc., and for the production of 600 tons per year @ Rs.20.00 per Kg., Value of up gradation will be Rs. 2.4 lakhs;
- As per fig. A4.1, assuming 2% of energy saving to produce 600 Tonnes per year & Energy consumption for firing the product @ 25% of product value Rs. 20.00/ per kg will be Rs. 5.00 per kg;
- 5% saving (@ Rs.5.00/ Kg) for 600 Tons = Rs. 0.60 lakhs

Totalling the above the payback amount will be Rs.3.00 Lakhs against the additional input of 2.4 lakhs.

Annexure 5.9 shows the defects in body and glaze and probable remedial measures.

# 6

# Problem areas and remedial measures in kilns

This chapter provides analyses of the performance of three different types of kilns viz. tunnel kiln, shuttle kiln and down draught kiln, used in Khurja pottery cluster. In order to evaluate the performance of these kilns and to identify possible energy conservation opportunities in the kilns, TERI conducted detailed energy audits of three representative units, each having a different type of furnace, in the cluster. On-site measurements were taken for monitoring different parameters of the kilns by using portable instruments. Details of the energy audits and the recommendations to improve the energy efficiency of these kilns are given below in separate sections.

## Tunnel kiln

The oil fired tunnel kiln used in unit B has an installed capacity of 2.25 tonne of product per day of stoneware crockery. The basic dimensions of the kiln are given in table 6.1. The schematics of the tunnel kiln in this unit are shown in figures 6.1 and 6.2. A typical tunnel kiln has three different zones, namely, preheating, firing and cooling zones.

The kiln has two ends; viz the loading end and the unloading end (figure 6.1). The green wares are stacked on trolleys, which move on the rails provided throughout the length of the kiln. For loading the greens and unloading the fired products, a side rail is provided parallel to the kiln. The proximity of the side rails to the kiln walls also helps in drying of the greens before they are fed in the furnace (figure 6.3).

During loading, greens are arranged in saggars[a] and stacked on the trolleys. The reason for using saggars for stacking the greens is that the trolleys are not equipped with decker plates for stacking the greens. The use of saggars is inefficient (from the point of view of energy consumption) compared to use of decker plates for stacking greens. The speed of the trolleys inside the kiln is

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[a] The unit internally manufactures the different kinds of saggars used for stacking in trolleys.

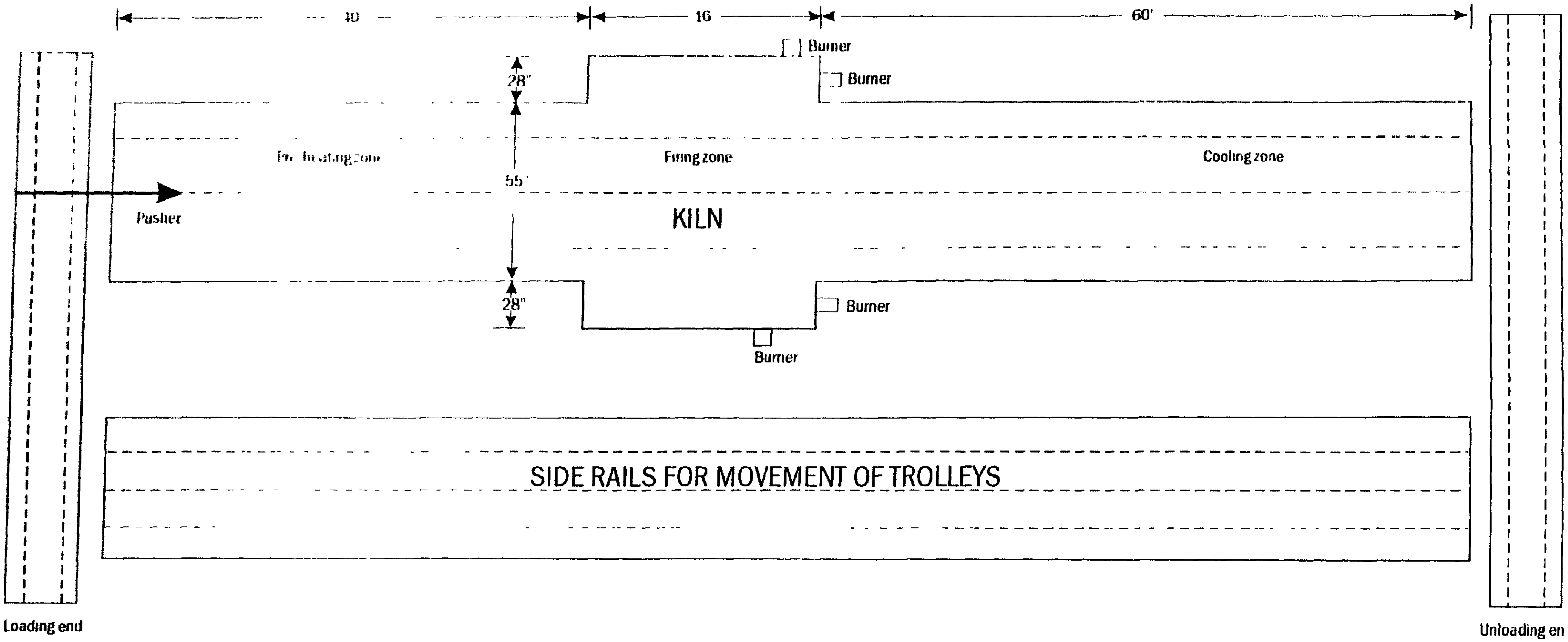

**Figure 6.1** Plan of the tunnel kiln

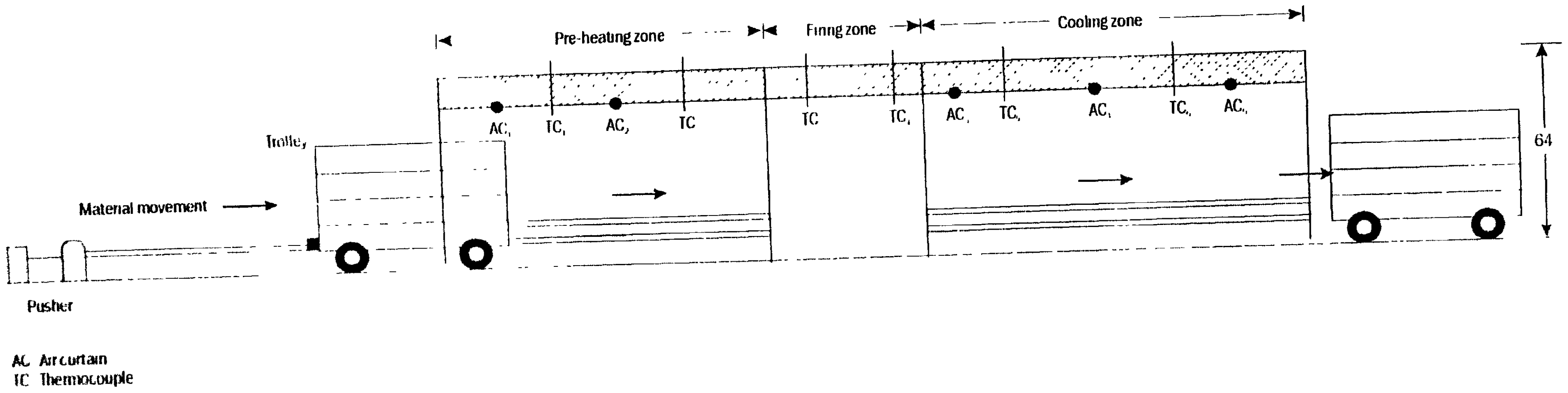

Figure 6.2 Sectional view of the tunnel kiln

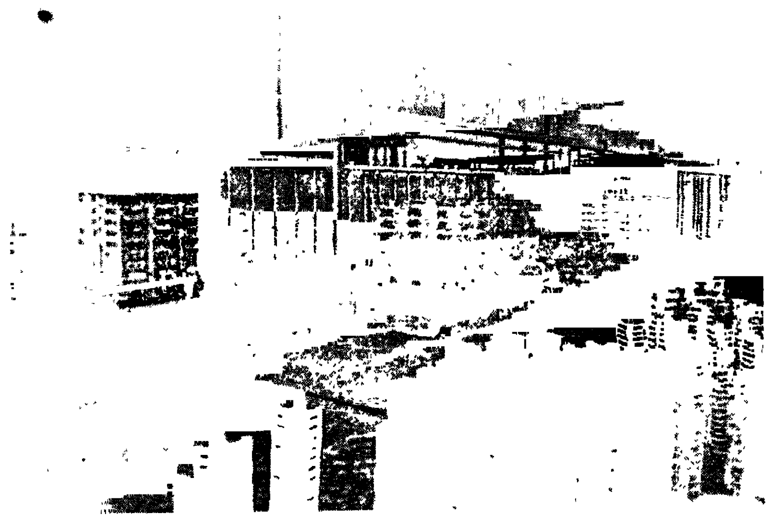

**Figure 6.3** View of tunnel kiln

controlled with the help of an electrically operated pusher. The pushing time is adjusted to provide the required residence time for the type of products being fired in the kiln. On an average, about 22 trolleys travel through the tunnel kiln in 24 hours.

**Table 6.1** Tunnel kiln dimensions

| | |
|---|---|
| Total length | 35.4 m |
| Preheating zone | 12.2 m |
| Firing zone | 4.9 m |
| Cooling zone | 18.3 m |
| Width | |
| Preheating & Cooling zones | 1.5 m |
| Firing zone | 2.9 m |
| Height | 1.6 m |

Four burners[a] (two large and two small burners) are located in the firing section. Each burner set, consisting of large and small burners, has two burners at right angles to each other (figure 6.1). For monitoring the firing conditions and temperature profile inside the kiln, six thermocouples are provided - two thermocouples each in the preheating, firing and cooling zones. The firing in the kiln is manually controlled by an operator, who changes the fuel to air ratio. There is also no monitoring of fuel-air ratio in the kiln and this ratio is adjusted by the operator(s) based on their experience and skills.

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[a] All the burners are of Wesman make.

To achieve better heat distribution inside the preheating zone and cooling zone, five air curtains are provided in the kiln (figure 6.2). Two air curtains are provided in the preheating zone and three air curtains are in the cooling zone. A common blower supplies pressurized air to the burner and the air curtains.

## Raw materials and products

The raw materials used in the preparation of greens are feldsper, quartz and clay. There are five common clays used in the preparation of clays: Bikaner pink clay –plastic, Bhuj clay, Than clay, Amrapali china clay –TT75 and Rajmahal clay. The ultimate analysis of the raw material composition shows that silica and alumina are the major constituents accounting for more than 95% by weight. The ultimate analysis of the body (greens) is given in annexure 6.1. The results of this analysis were used for calculating the reaction heat for the products fired in the kiln.

The unit produces about 10 different types of crockery-ware. The details of weight of different products fired on the day when energy audit was conducted are given in table 6.2. As can be seen, the weight of greens lies in the range 95–213 gm except for Pyala–5 inch whose weight is the maximum (415 gm). The total weight of the greens fired in a day is about 2.7 tonne. The weight of the fired products is lower than that of the greens. The loss in weight of the fired products is mainly attributed to the loss of moisture from the greens during the firing.

As mentioned earlier, saggars are used for stacking the products on the trolley. Seven different types of saggars are used for stacking the above mentioned products. The weight of each type of saggar is given in table 6.3. The total weight of saggars that pass through the kiln in a day is about 6380 kg, which is about 236% of the weight of the greens fired per day. The weight of saggars has important bearing on the kiln efficiency because saggars absorb heat inside the kiln, which results in heat loss.

**Table 6.2 Weight of products fired in tunnel kiln**

| Product | Weight of green[a] (gm) | Weight of fired product (gm) | Loss in weight (gm) |
|---|---|---|---|
| Love mug | 145 | 138 | 7 |
| Love medium | 123 | 117 | 6 |
| Love Premium | 117 | 110 | 7 |
| Shiva mug | 135 | 120 | 15 |
| Cup | 102 | 94 | 8 |
| Hotelware | 205 | 182 | 23 |
| Saucer | 144 | 139 | 5 |
| Soup-6 inch | 213 | 195 | 18 |
| Pyala-5 inch | 415 | 378 | 37 |
| Chuski cup | 95 | 86 | 9 |

**Table 6.3 Weight of saggars used in tunnel kiln**

| Saggar type | Weight of saggar (gm/piece) |
|---|---|
| Small cup | 3.10 |
| Medium cup | 2.05 |
| Saucer | 0.40 |
| Pyala-5 inch | 0.94 |
| Soup-6 inch | 0.599 |
| Mug | 3.075 |
| Top plate | 3.60 |

Saggar-to-greens ratio = 2.36 kg/kg

Ratio of dead weight to greens = 5.9 kg/kg

## Performance of tunnel kiln

Tunnel kiln is a continuous type steady state kiln where the temperatures in different zones of the kilns are maintained constant. The temperature profile of the kiln in preheating, firing and cooling zones were observed from the panel. A typical temperature profile of the tunnel kiln is shown in figure 6.4. The inlet temperature of the goods was 44°C and the outlet temperature of the fired products was 162°C.

## Heat balance of tunnel kiln

The performance of the kiln was monitored by measuring heat inputs and various heat losses associated with the kiln. The heat input is calculated by monitoring the HSD consumption in the kiln. Different losses associated with the kiln are structural loss, flue gas loss, heat loss to the dead weight of trolley

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[a] Greens - Product before firing

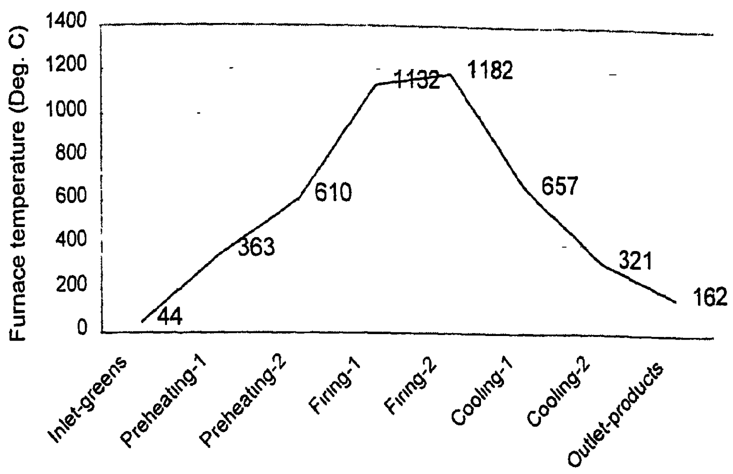

**Figure 6.4** Temperature profile of the tunnel kiln

and saggars and residual heat losses in product, saggars and trolley structure. The measurements taken for analysis of heat balance are given below.

## *Measurements taken*

Different parameters that were monitored/measured to carry out heat balance of the tunnel kiln are:

- Fuel (HSD) consumption
- Temperature of preheating, firing and cooling zones
- Temperature of surfaces of kiln
- Analysis of flue gases – oxygen, carbon monoxide and temperature
- Inlet and outlet temperature of greens, fired products and saggars
- Weight of greens, fired products and saggars
- Ambient conditions – temperature and relative humidity

Samples of HSD, greens, glaze and fired product were collected and analyzed for their constituents. The samples of greens, glazes and fired products were tested by CGCRI and their findings are reported in chapter 5. The test results for the HSD sample are given in annexure 6.2.

A heat balance of the kiln is shown in table 6.4 and figure 6.5 below.

**Table 6.4** Heat balance of tunnel kiln

| Component | Heat component | |
|---|---|---|
| | Kcal/hr | Fraction (%) |
| Heat loss for moisture removal in product | 3845 | 2.1 |
| Reaction heat | 22333 | 12.3 |
| Residual heat loss in product | 2102 | 1.2 |
| Heat loss in trolley and saggars | 10157 | 5.6 |
| Structural loss | 61673 | 33.8 |
| Flue gas loss & unaccounted heat loss | 82196 | 45.1 |
| Total heat input | 182306 | 100.0 |

Out of the total heat input, heat loss in flue gas accounted for majority of heat losses (45.1%). This is because of large level of excess air handled inside the tunnel kiln. In tunnel kiln, apart from combustion air, a large quantity of air is required for maintaining the required temperature profile in preheating and cooling zones. The second major heat loss is structural loss (33.8%), which is due to the huge surface area of the kiln (161 $m^2$). The heat loss due to deadweight of saggars and trolley structure accounts for 5.6%, which offers some scope for improvement.

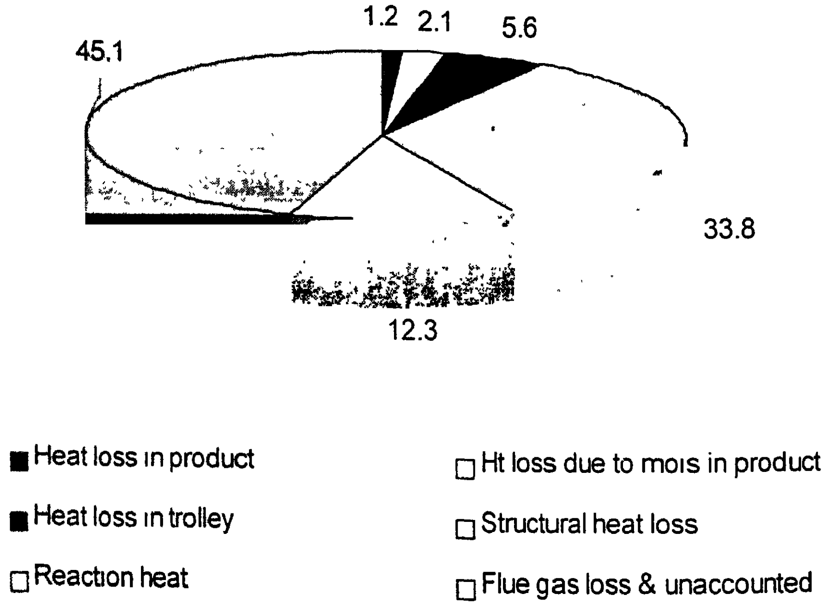

**Figure 6.5** Heat balance of tunnel kiln

## *Thermal efficiency and specific energy consumption*

From the results of energy audit, the thermal efficiency and specific energy consumption of the kiln were calculated. The thermal efficiency of the kiln is defined as a ratio of the heat required for firing the greens to the total heat input to the kiln. The specific energy consumption is the ratio of total heat input to the quantity of production (in terms of kcal per kg of greens). The figures for thermal efficiency and specific energy consumption are given in table 6.5.

**Table 6.5** Performance of tunnel kiln

| | | |
|---|---|---|
| **Thermal efficiency of the kiln** | - | 14.4% |
| **Specific energy consumption of tunnel kiln** | - | 1620 kcal/kg green |

## *Recommendations*

Based upon the observations made during the field visits and from the results of energy audit, few technological options are provided in this section to improve the energy efficiency of the kiln. For each recommended technological option, a techno-economic analysis is provided to highlight the viability of the recommendation. Although the details given here pertain only to the unit where the energy audit was carried out, but these recommendations are applicable in general for all tunnel kiln operating in Khurja cluster. This is because most of the tunnel kilns in Khurja have similar designs and operating practices.

### Use of auto on–off burners

The existing burners are operated manually wherein adjustment of oil flow is made as noticed by the operator. There is not much control over the combustion airflow. Any negligence on the part of operator will not only result in over-firing or under-firing of the products but also lead to higher energy consumption. An automatic burner with ratio-controller which switches on or off as per the temperature prevailing inside the firing zone would help in avoiding such over/under firing leading to optimum fuel consumption. Such burners are also available in market e.g. FBR (Italy)/Benton/Ecoflame. The automatic burners offer close control over the operating parameters, thus offering good potential for energy savings. Reduction in fuel consumption of the order of 10% is possible by using such a system. The investment required for such a system, which includes burners and control panels, is around Rs 3.5 lakhs. The simple payback period for this measure is around 1.7 years.

A case study where auto on-off burners were installed in the tunnel kiln is given below.

**Case study**

A case study of a tunnel kiln in Ahmedabad pottery cluster showed the following improvements in the kiln performance with incorporation of auto on–off burner.

Oil consumption before retrofit = 1250 lit/day

Oil consumption after retrofit with auto on-off burner = 1000 lit/day

Savings = 250 lit/day (~ 20%)

Assuming 330 days of operation,

Annual savings = 82.5 kL (Rs 12.4 lakh)

## Reducing dead-weight of trolley

The dead weight of the trolley is additional source for heat loss. The trolley mass is heated to the firing temperature along with the product, which is a complete waste of heat. In the trolley structure, refractory bricks account for about 65% of the trolley weight. Reducing by about 30% the dead weight of the refractory material used in the trolley can minimize the heat loss in the trolleys[a].

For quantifying the energy savings, it is assumed that reduction of dead-weight of refractory material is done for all trolleys (typically, 22 trolleys are heated upto firing temperature every day). It may be difficult to visualize the savings if the above exercise is carried out for one or few trolleys alone. The cumulative effect due to weight reduction of trolleys is shown in table 6.6. The investment required for adopting this measure is around Rs 3.1 lakhs.

**Table 6.6** Effect of reducing dead-weight of refractory material in trolley

| | | |
|---|---|---|
| Total weight of refractory material | - | 5610 kg |
| Existing refractory to product ratio | - | 2.1 |
| Anticipated reduction in refractory material | - | 30% |
| Refractory to product ratio after weight reduction | - | 1.5 1 |
| Reduction of heat absorbed by refractory material | - | 7% |
| Anticipated reduction in HSD | - | 32 lit/day |
| Monetary savings | - | Rs 1.60 lakh per year |

## Use of decker plates in place of saggars

Replacement of existing saggar based stacking arrangements by decker plates will lead to increase in production, because more material can be stacked per unit volume. Calculations show that by using decker plates the production level can be increased by 30%[a], which would result in annual fuel savings of Rs 1.73 lakh[b]. This is due to the fact that for the production level is increased keeping other heat loss factors (such as structural loss, flue gas loss, heat loss in dead-weight) almost constant. Additionally, the life cycle of decker plates is better than conventional saggars. The life cycle of saggars is only 4 to 5 firing cycles whereas the life of decker plates is more than one year. Taking into account the present cost incurred by the unit for making saggars, an additional investment of Rs 1.5 lakhs would be incurred for installing decker plates in trolleys. Initial investment required for changing over 30 trolleys with decker plates arrangement is estimated at Rs 7.5 lakhs.

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[a] Discussions were held with suppliers about the possible weight reduction in the refractory material.

## Provision of alarm for limiting temperature conditions

The tunnel kiln is operated manually. It does not have any control system to monitor/control the temperature of the firing zone. Any fluctuations in temperatures inside the firing zone, due to changes in loading pattern of the trolleys, are either not taken care of or done after some time lag by the operator, leading to loss in fuel as well as quality of the fired product. A simple alarm system, which would produce alarm for two temperature levels (one upper limit and one lower limit), would help the operator to take necessary action and help in minimizing such problems. The cost of such alarm, which has a controller with two relays, would be about Rs 3000 per set. Annexure 6.3 shows the colour of flame at different temperatures that would help the operator in optimizing furnace operation.

## Improvement of kiln insulation

### *High alumna coating in firing zone*

The firing zone has been provided with veneer mortar in the corners only. This leads to higher heat losses from the firing zone and erosion of ceramic fibres. It is suggested high temperature alumna coating be applied over the entire inner surface of the firing zone. This heat protecting reflective coating helps in retaining the heat inside the firing zone thus helps in minimizing heat losses from firing zone.

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[a] Checked by carrying out actual loading on the platform of the trolley

[b] For calculating the energy savings, it is assumed that the weight of saggars per trolley will be equal to that of decker plates.

### *Provide aluminum cladding at the back of the ceramic fibre module*

At present, the tunnel kiln does not have any covering outside the furnace. Apart from helping in protecting the furnace insulation, the outer covering also helps in reducing the heat losses from outer surfaces of the kiln. An aluminium cladding over the outer surface reduces the existing heat losses due to lower emissivity value of the cladding.

### *Improving the quality of insulation lining in the firing zone*

The surface temperature of firing zone of the tunnel kiln was found to be quite high (60–128°C). The higher level of surface temperatures may be due to:
Less insulation thickness of the wall at the firing zone, which may be less than the optimum insulation thickness. The insulation lining thickness for the firing zone is based on certain design parameters such as inside temperature of furnace and type of insulation. Optimum thickness of insulation is the thickness which leads to minimum heat loss with minimum thickness of insulation, beyond which the reduction in heat loss does not vary much.
Lower density of ceramic fibre modules are used in the firing zone of the kiln which leads to increased heat loss from the firing zone. Proper density of ceramic fibre, as recommended by the manufacturer, must be used for the firing zone.

Use of improper holding anchors for making modules. Presently, locally available holding anchors are used which may get deformed due to higher temperatures. Hangers made of SS310 are normally recommended for firing zones for preparing modules of ceramic fibres. However, this requires an additional investment of Rs 50 per hanger (local hangers cost Rs 20 per pieces whereas SS310 hangers cost Rs 70 per pieces).

## Burner operation

### *Combustion air*

The combustion air was selected for lean flame. Low air pressure flame inside the furnace indicates localized heating which may cause under–firing of bottom layer of products in the trolleys. The combustion air setting should be selected physically by checking the flame nature through peephole, which must be bright whitish colour.

### *Atomizing air*

It was also observed during the energy audit that the atomizing air in one of the burners was less. Under normal operating conditions, the atomizing air should always be full. Use of less atomizing air will result in poor combustion efficiency and improper flame temperatures. It is recommended that as a regular housekeeping measure, air pipelines should be checked regularly for clogging and such problem must be rectified immediately. Such exercise must be performed during the regular shutdown of the tunnel kiln.

## Sealing of firing zone from cooling and preheating zones

The existing sealing of firing zone from preheating and cooling zones was observed to be about 4 inch (100 mm). However, this is higher than the norms recommended for a tunnel kiln. The larger gaps would lead to escaping of more heat from the firing zone to other cooler parts of the furnace such as preheating and cooling zones. An optimum sealing of 2 inch (50 mm) is recommended which would provide a better sealing between different heat zones. This helps in reducing the heat dissipation and hence the fuel consumption of the kiln.
The sealing must be done physically by increasing the height of material or permanently providing modules with more height. There are two methods of providing sealing inside the firing zone. Sand sealing can be done which however poses maintenance problem. An alternative is ceramic strips, which can be pasted on the sides of the trolley for avoiding heat loss to cooling and preheating zones.

## Provision of inlet filter for the blower

Presently, the blower operates without any inlet air filter. Since the ambient environment contains a lot of dust, the blower sucks in dust particles along with air and carries them inside the kiln. This may cause fine spots on the glaze and also choking of air pipes. Provision of an inlet filter, of cartridge type (10 μ foam), at the blower inlet to remove the dust particles would help in avoiding fine spots on the product and choking of pipes. The cost of the cartridge type filter is about Rs 500 and can be of reusable or disposable type.

## Use of baffle wall inside firing zone

The present heating inside the firing zone is not uniform as is evident from the uneven firing of the products and over-firing in certain locations. To avoid this, and to improve the distribution of heat inside the firing zone, a baffle wall may

be constructed at an angle to the flame. The wall may be constructed of refractory bricks with 40–50% openings provided in the structure, which allows part of the heat to flow out and the rest to get distributed inside. The wall will be a temporary structure and need not be cemented to the base so that if there are any problems found to be associated with the wall, it can be dismantled easily during the shutdown. However, this wall should be constructed on a case to case basis after studying the heat distribution inside the furnace. Such tunnel kilns with baffle arrangements are already in use in Ahmedabad pottery cluster.
The auxiliary burner may be cut off with use of baffle plate wall. This is expected to reduce the fuel consumption by about 30%, which amounts to Rs 7 lakh per year (47 kL of HSD). The construction costs for the baffle wall is very less compared to the amount of savings.

## Maintaining air flow through kiln

It was observed the present draft available at chimney is less. Proper draft must be maintained from the cooling zone to the preheating zone using a combination of natural draft and/or forced draft. Proper draft is a must to ensure better heat distribution inside the kiln. During the energy audit, it was also found that the chimney sucks air from bottom whereas ideally this location should be from the top.

## Optimizing blower power

The tunnel has at present a single blower that caters air for combustion, air curtain and cooling purposes. However, air requirements for maintaining air curtains need not have high pressure but require higher volumes. A separate blower, which maintains an air pressure of 8 inch WG, may be installed to cater for requirements of air curtain. The present burners require approximately a total power of 1 kW for supplying combustion air at higher pressures, which is equivalent to the present level. The total power requirements would come down from 5 hp to 3 hp that would result in savings of Rs 30000 per year (11800 units of electricity).

## Changeover from HSD firing to LPG firing

All tunnel kilns in Khurja use HSD as fuel. Changing over from HSD to LPG as fuel would improve the thermal efficiency of the kiln. Also the existing specific cost of LPG is about 8% lower than that of HSD. However, such changeover needs investments for burner and change in layout of burners in the kiln. Table 6.7 shows savings due to changeover to LPG. These savings have been worked out with present LPG cost, which can vary significantly if the international prices fluctuate. It must be noted that any upward movement in cost of LPG will make the LPG usage unviable in the tunnel kilns.

**Table 6.7** Cost benefits with changeover to LPG

| | | |
|---|---|---|
| Present HSD consumption | - | 478 lit/day |
| Cost of HSD | - | Rs 15.05 per lit |
| LPG heat equivalent | - | 366 kg/day |
| Cost of LPG | - | Rs 18.00 per kg |
| **Direct cost savings with LPG changeover** | - | **Rs 1.98 lakhs** |
| Investments | - | Rs 1 61 lakh |
| **Simple payback** | - | **< 1 year** |

## Shuttle kiln

The kiln used in the Units C is a side fired shuttle kiln using four short flame oil-fired burners. The kiln is batch-operating kiln with a cool-to-cool cycle of 24 hours. The firing and cooling cycles are approximately 12 hours each. The schematic diagrams of the shuttle kiln used in Unit C are shown in figures 6.6 & 6.7 and the dimensions of the shuttle kiln are given in table 6.8. The kiln has one loading door and one unloading door, which are used to slide the trolley in/out of the kiln. Two burners each are provided on the sides of the loading and unloading doors of the kilns (figure 6.6). A 7.5 hp blower, having a capacity of 600 cfm at 40" WG pressure, supplies the combustion air and cooling air to the kiln.

**Table 6.8** Dimensions of shuttle kiln

| | | |
|---|---|---|
| Length of kiln | . | 4 25 metre |
| Width of kiln | | 2 32 metre |
| Height of kiln | | 2.25 metre |

Since the greens that are loaded on the trolley are not of uniform size, a careful loading arrangement has to be done to achieve optimum packing density. Non-uniform loading of wares ensures that hot-spots do not develop inside the kiln resulting in under-firing or over-firing of wares. Two thermocouples located on the furnace indicate the inside temperatures of the kiln during the entire cycle of operation. Firing inside the kiln is controlled manually by the operator by gradually increasing the fuel supply to get the required temperature gradient. The ratio controllers provided on the burners deliver fixed ratio of air to oil to the furnace. Once a temperature of about 1100°C is reached inside the kiln, the temperature is kept constant for about 3 hours (the "soaking period") to enable effective firing of glazed products.

After soaking of the products is complete, the fuel supply to the burners is cut off and only cooling air is supplied to the kiln. The accelerated cooling through air blowers is done to maintain a cooling temperature gradient for the wares. Forced cooling through air blower is carried out till the kiln temperature has dropped to about 300°C, after which the blower is stopped and the doors are opened for natural cooling of the products.

The exhaust to the chimney is drawn from the bottom holes provided at the kiln doors. The exhaust from both sides join on to a common chimney, which is directly exposed to the atmosphere (figures 6.6 and 6.7). The kiln does not have any waste heat recovery system to recover and utilize the waste heat from the high temperature exhaust gases.

## *Raw material and products*

The raw materials used for making the stoneware items are quartz, feldspar, clay (china clay and ball clay). The ultimate analysis of raw material composition shows that silica and alumna are the major constituents accounting for more than 87% by weight. The ultimate composition of body (green) is given in annexure 6.1.

The unit produces items such as plates, bowls, etc., which vary greatly in their sizes and weights. These products, with large differences in weight, are normally fired in the same batch (table 6.9). Since the trolleys have decker plates for stacking the products, therefore saggars are used only for stacking of plates. During the audit, seven types of saggars are used in the kiln. The ratio of dead weight of trolley and saggars to that of the greens is about 6.95.

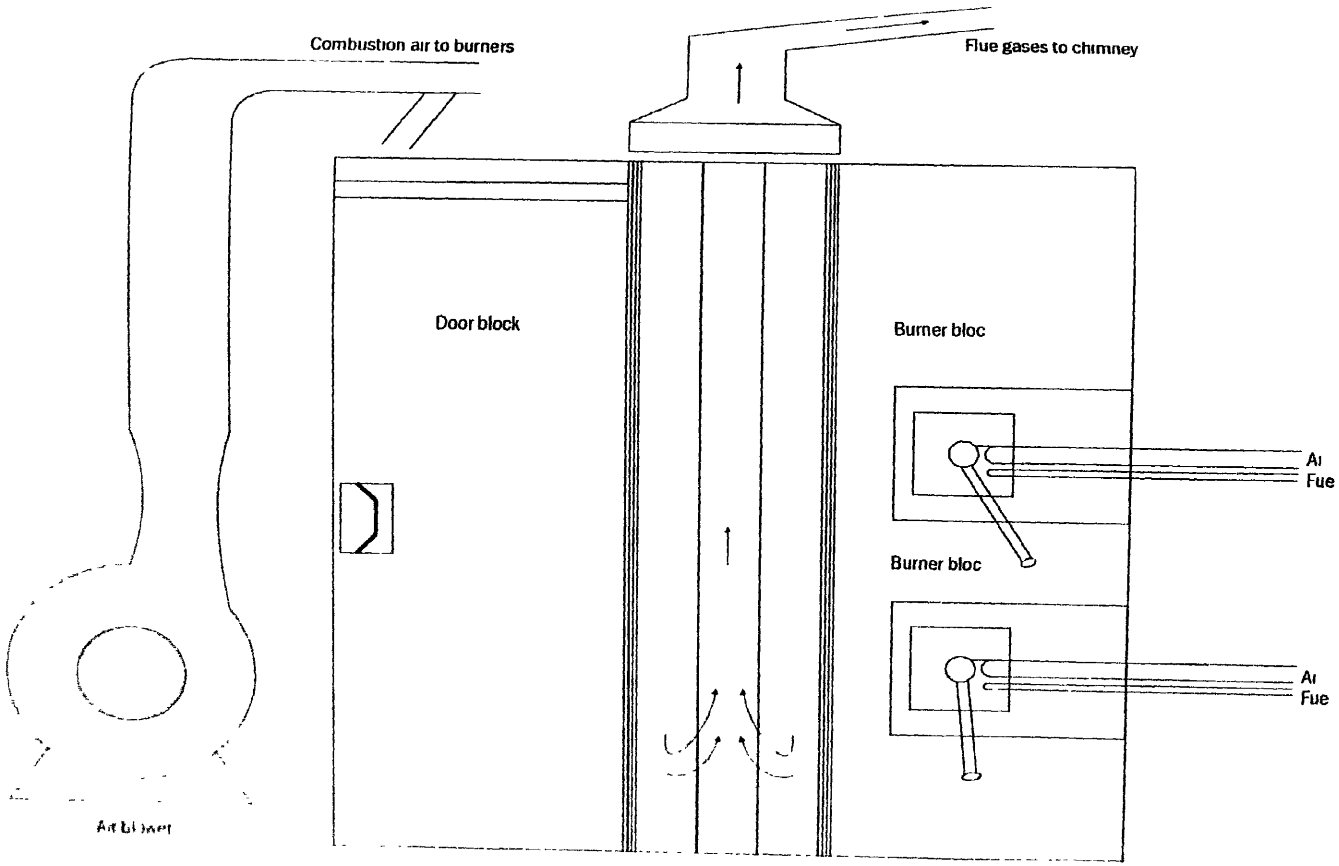

Figure 6.6 End view of shuttle kiln

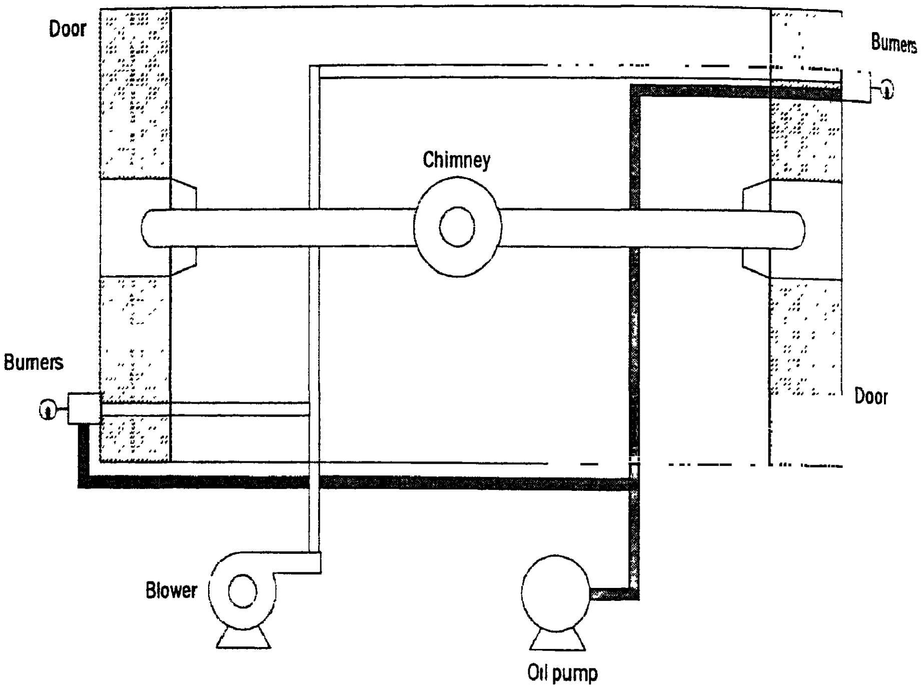

**Figure 6.7** Top view of shuttle kiln

**Table 6.9** Weight of products fired in shuttle kiln

| Type | Greens with glaze (gm) | Fired (kg) |
|---|---|---|
| Handi no 3 | 0.460 | 0.420 |
| Sugar pot + cup | 0.195 | 0.190 |
| Mug | 0.196 | 0.140 |
| Oval dish | 0.510 | 0.470 |
| Quinch dish | 0.830 | 0.795 |
| Full plate | 0.670 | 0 655 |
| Bowl ZS | 0.300 | 0.290 |
| BNB Bowl No 1 | 0 220 | 0.202 |
| Katon | 0 150 | 0 145 |
| Glass | 0 200 | 0 195 |
| Curry bowl no 3 | 1 580 | 1.420 |
| Gamla set | 1.030 | 0.975 |
| Water jug | 0.850 | 0 785 |
| Quarter plate | 0.295 | 0.275 |
| Saucer super | 0.160 | 0.150 |
| Large bowl 10" | 1.210 | 1.100 |
| Half plate | 0.505 | 0.470 |
| Donga DP no 2 | 0.910 | 0.835 |
| MB Bowl no 1 | 0.948 | 0.870 |
| Soup Bowl | 0.240 | 0.220 |

| Type | Greens with glaze (gm) | Fired (kg) |
|---|---|---|
| BP Bowl No 1 | 0.845 | 0.775 |
| BP Bowl No 3 | 0.382 | 0.350 |
| Chota Spoon | 0.013 | 0.012 |
| Spoon Number 100 | 0.028 | 0.026 |
| ODA Spoon | 0.055 | 0.050 |
| Spoon | 0.033 | 0.026 |

## *Performance of shuttle kiln*

The temperature profile of shuttle kiln from start-up to shutdown was monitored (figure 6.8). The heating cycle shows the furnace is heated at a rate of 88°C per hour whereas the cooling rate was achieved at 72°C per hour.

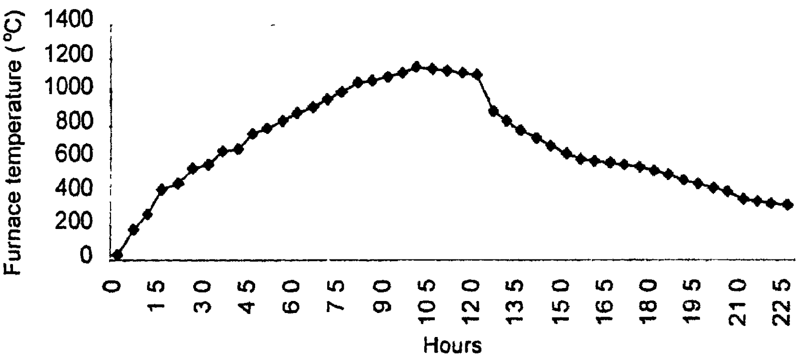

**Figure 6.8** Temperature profile of the shuttle kiln

## *Heat balance of shuttle kiln*

The performance of the kiln was monitored by measuring heat inputs and various associated heat losses. The heat input is given by the HSD consumption in the kiln. Different losses associated with the kiln are structural loss, flue gas loss, heat loss to the dead weight of trolley structure and saggars and residual heat losses in product, saggars and trolley structure. The measurements taken for analysis of heat balance are given below.

## Measurements taken

The following parameters were monitored for a detailed analysis of the heat balance of shuttle kiln:

### Fuel consumption

Temperature of heating, soaking and cooling cycles
Temperature of surfaces of kiln
Analysis of flue gases – oxygen, carbon monoxide and temperature
Inlet & outlet temperatures and weights of greens, fired products, trolley structure and saggars.
Ambient conditions – temperature and relative humidity

Samples of greens, glaze and fired product were collected and analyzed for their constituents. The samples of greens, glazes and fired products were tested by CGCRI and their findings are reported in chapter 5. Since shuttle kiln is a batch type kiln, flue gas and surface temperatures were monitored periodically (for every hour) to measure the increase in heat loss rates.

Based on the above measurements and other data collected from the unit, a detailed energy balance of the kiln was carried out. Detailed heat balance calculations are provided in annexure 6.4. The heat balance of the shuttle kiln is shown in figure 6.9. Out of the total heat input to the kiln (3912127 kcal/batch), major heat losses are flue gas loss and structural loss, both of which account for 68.3% of total heat input. The temperature of furnace outer surfaces was monitored for every hour during heat cycle to determine the profile of surface heat loss for the kiln. The structural heat loss in the shuttle kiln is shown in figure 6.10.

Apart from flue gas loss, about 17.5% of the input heat is carried away by cooling air which removes heat from furnace internals during cooling cycle. Other heat losses account for about 14% of heat input. The thermal efficiency and specific energy consumption of the kiln are given in table 6.10.

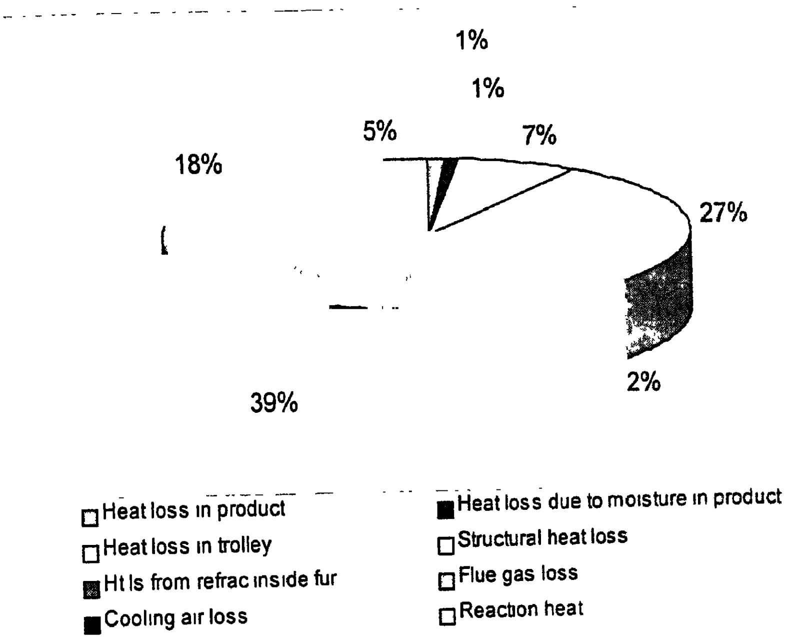

Figure 6.9 Heat balance of the shuttle kiln

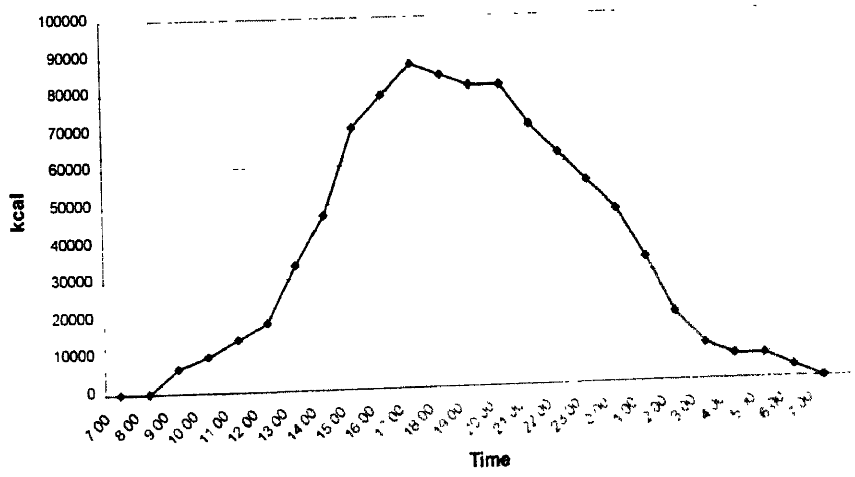

Figure 6.10 Structural heat loss

Table 6.10 Shuttle kiln efficiency

| | | |
|---|---|---|
| Thermal efficiency of the kiln | . | 5.6% |
| Specific energy consumption | . | 4822 kcal/kg green |

## *Recommendations*

### Use of recuperator or recuperative burner

Shuttle kiln is a batch type kiln. Unlike tunnel kilns, there are no separate preheating, firing and cooling zones. The entire mass is heated in a closed insulated chamber to the firing temperature, soaked at the maximum temperature (1128°C) for some period and then cooled gradually. Due to this, the flue gas losses vary with time (annexure 6.5) which increases till the soaking period and falls down during cooling cycle.

A waste heat recovery system can be incorporated in the flue gas circuit to extract the waste heat available in flue gases (39% of heat input). To accomplish this, either a recuperator or a recuperative burner can be used in the shuttle kiln for preheating the combustion air. Assuming that the combustion air is preheated upto 400°C by using either a recuperator or recuperative burner, fuel savings upto the extent of 11% are possible. Table 6.11 shows the cost savings with use of recuperator.

**Table 6.11** Cost benefit analysis of using recuperator

| | | |
|---|---|---|
| Assumption: | | |
| 1 Secondary air (90% of total combustion air) is preheated in recuperative burner | | |
| 2. For initial 3 hours, when the temperature of flue gas is lower, secondary air is preheated upto 100°C; then the preheat temperature raises upto 400°C. | | |
| Total HSD savings | = | 51.4 lit/batch |
| | = | Rs 110000 (7.7 kL/year) |
| **Investments**<br>(Investment includes recuperator, burners, SS piping and fabrication) | = | Rs 7.00 lakhs |
| Simple payback | = | 6.3 years |

### Lagging of furnace

It was noticed during energy audit that heat loss from some portion of the surfaces in the furnace were found to be higher. This is due to the 'worn out' insulation, which needs replacement. Reduction of heat losses with improved insulation reduces fuel consumption. Assuming that simple house-keeping measures like replacement of 'worn out' insulation leads to reduction in temperature which equivalent to other surfaces in the furnace, it would lead to a fuel savings up to the extent of 2.5% (Rs 25000 per year). Regular maintenance of insulation of the kiln is required which would help in minimizing the structural losses from kiln walls.

## Downdraft kiln

Downdraft kilns are traditional kilns used in Khurja pottery cluster. These are batch type kilns using natural draft (i.e. they do not require blower or any fan for their operation). A schematic of downdraft kiln is shown in figure 6.11. Energy audit of a typical downdraft kiln was carried out during the study for making a comparison with tunnel and shuttle kilns. The details of the unit are given in table 6.12. The internal diameter of the kiln monitored was 17 ft. The unit manufactures LT insulators. Dried greens are manually put in saggars and stacked into the kiln manually. There is a center block of stack surrounding which are five concentric circles of stackings. The material is stacked up to the kiln roof (crown) leaving room for the flue gases to pass around the stackings. After loading the door is closed with brick structure on mud mortar. There are seven bag houses (fireboxes) with fixed grates for coal firing.

Table 6.12 Unit details of downdraft kiln monitored

| | |
|---|---|
| Type of operation | Batch type |
| Internal diameter of the kiln | 17 ft |
| Product | Insulators |
| Fuel | Coal |
| Rejection rate | 10-15% |

The fire is initiated in all the bag houses with waste tire pieces and diesel. Once ignited, coal is fed manually in each of the fireboxes at regular intervals. However, the quantity of coal fed is generally not monitored in the kiln. After about 4 hours of firing when the inside temperature is in the range 250–300°C, the side holes above fireboxes are closed down (figure 6.12). By this time, all the moisture present in greens would have been driven out. The top central hole is closed down after about 14 hours of firing (when the temperature inside reaches 750–950°C. Flue gases leave through the holes in the floor leading to flue channels lead to the chimney. The firing cycle followed in the downdraft kiln during monitoring is given in table 6.13. The entire cycle lasts approximately 5 days.

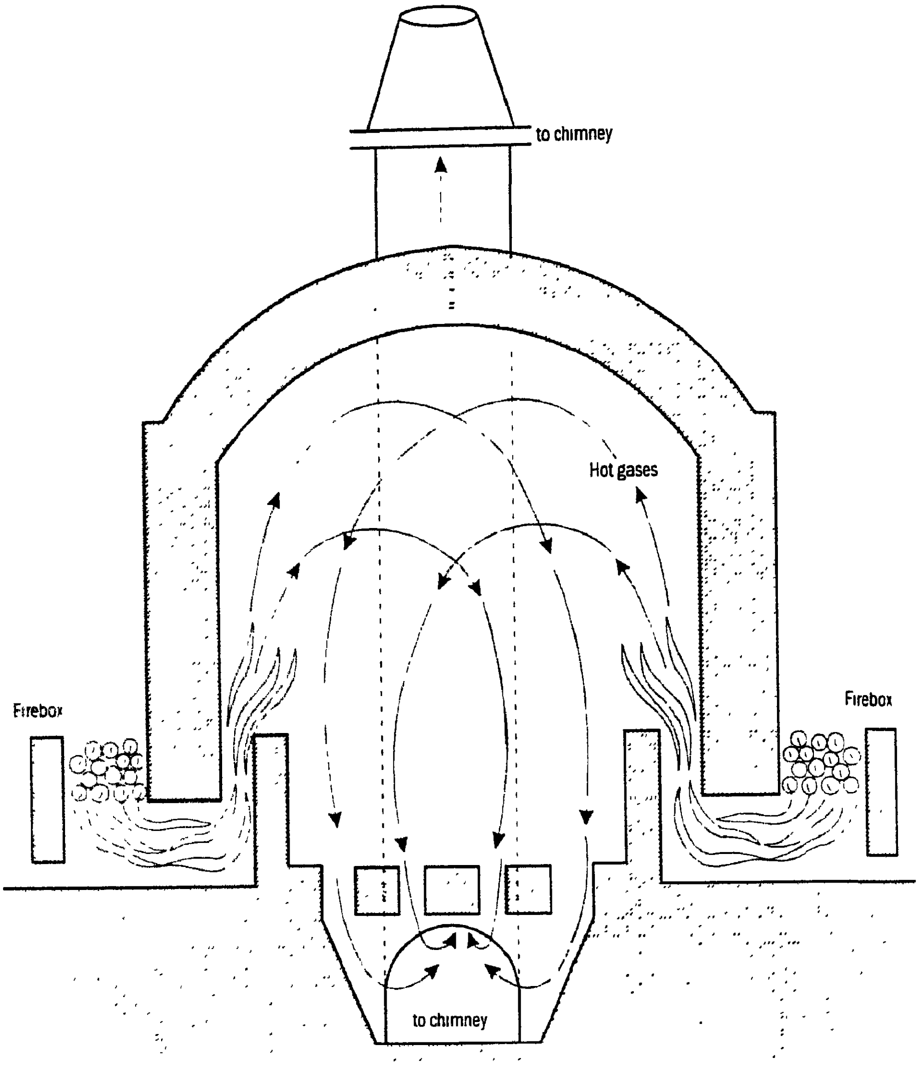

Figure 6.11 Schematic diagram of a downdraft kiln

Table 6.13 Operating cycle in downdraft kiln

| | |
|---|---|
| Firing | 30 hr |
| Soaking | 4 hr |
| Cooling | 80 hr |
| Total | 114 hr |

Figure 6.12 Firing in a down-draft kiln

The condition of the product is checked for its level of firing by manually drawing samples from sides. The inside temperatures of the furnace are not known to the operator, as no temperature indicators are used for monitoring. Significant amount of heat is absorbed by the kiln structure itself, as the kiln (constructed with refractory bricks and red bricks) is a heavy structure weighing approximately 161 tonne which absorbs heat during firing and dissipates heat to the atmosphere during cooing process.

## *Measurements taken*

The different parameters that were monitored to study the kiln performance and the frequency of the measurements taken is shown in table 6.14 In addition to the above parameters, samples of the two grades of the coals used during firing were collected and analysed (annexure 6.6).

Table 6.14 Measurements taken in downdraft kiln

| | |
|---|---|
| Furnace temperature (taken from side holes) | Hourly readings, approximately 120 readings |
| Furnace temperature (taken from the holes in the furnace crown) | Hourly readings approximately 120 readings |
| Flue gas temperature | Hourly readings, approximately 120 readings |
| Surface temperatures | Taken randomly during the firing cycle |
| Flue gas analysis | Measurements taken during firing cycle |
| Coal consumption (separately for the two grades of coal used at the unit) | Initial weight and balance coal left after the firing process noted |
| Weight of greens, fired products and saggers | Average of three samples each |
| Ambient conditions | Temperature and relative humidity |
| Ash temperature | 12 readings |
| SPM emissions (separately for charging and non-charging periods) | Total of 5 readings |

## Performance evaluation of the downdraft kiln

The performance of the downdraft kiln was monitored for its energy and environmental fronts. The temperature of downdraft kiln was monitored by mounting thermocouples in the kiln. The furnace temperatures on top and sides and flue gas temperature were monitored during the study (figure 6.13). The temperature gradually rises during the firing and soaking periods and drops down during the cooling cycle.

## Heat balance of downdraft kiln

Based on the measurements taken and the analysis carried out, a detailed heat balance of the downdraft kiln was carried out (table 6.15). Since downdraft kilns are batch operated, the entire structure has to be reheated during every cycle. This energy requirement for the heat absorbed by the kiln structure of high thermal mass together with structural loss accounts for 35% of total heat input. The dry flue gas loss is calculated to be 21%. Other heat losses are due to: (i) formation of CO (carbon monoxide) instead of carbon dioxide (6%), and (ii) unburnt carbon in bottom ash (2.6%).

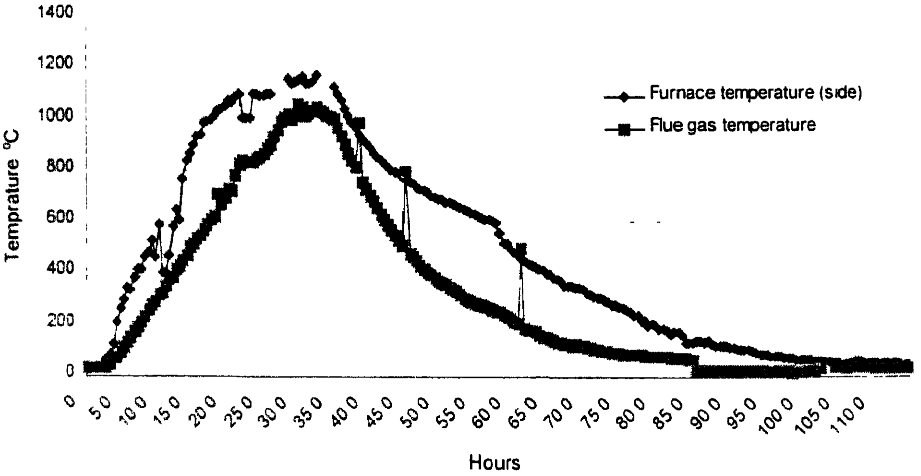

**Figure 6.13** Temperature profile in a downdraft kiln

Table 6.15 Heat balance and efficiency of downdraft kiln

| Heat losses | kcal | |
|---|---|---|
| Moisture removal from greens | 644472 | Percentage |
| Reaction heat | 1622327 | 0.9 |
| Residual heat loss through product | 58564 | 2.2 |
| | | 0.1 |
| Heat absorbed by the kiln structure | 12880689 | |
| Structural loss | 13796830 | 17.1 |
| | | 18.3 |
| Dry flue gas loss | 15676385 | |
| Heat loss due to CO formation | 4523904 | 20.8 |
| Heat loss due to moisture and hydrogen in fuel | 4675600 | 6.0 |
| Heat loss due to moisture in air | 375009 | 6.2 |
| | | 0.5 |
| Unburnt carbon loss from bottom ash | 1960435 | |
| Sensible heat loss from bottom ash | 367914 | 2.6 |
| | | 0.5 |
| Cooling air & unaccounted loss | 18695148 | |
| | | 24.8 |
| Total heat input | 75251330 | 100.0 |
| Specific energy consumption | 4296 kcal/kg green | |
| Thermal efficiency | 3.0% | |

The specific energy consumption of the down draft kiln is 4296 kcal per kg of greens and the thermal efficiency of the kiln is 3.0%. The environmental performance of the kiln was monitored for coal charging and non-charging conditions (table 6.16). The SPM emissions also depend on the charging rates of coal in the kiln.

Table 6.16 SPM emissions from downdraft kiln

| Monitoring period | SPM emissions (mg/Nm$^3$) |
|---|---|
| Fire holes open position | |
| Charging | 1453 |
| Non-charging | 119 |
| All holes in kiln closed | |
| Charging | 2603 |
| Non-charging | 185 |
| Both charging and non-charging | 2603 |

## *Recommendations*

As can be seen from the heat balance calculations and the results of the dust emission monitoring of the representative kiln, the downdraft kilns are highly polluting and have energy consumption levels that are well above the levels achievable in tunnel kilns. The specific energy consumption of down draft kiln, tunnel kiln and shuttle kiln for manufacturing stoneware crockery are 6262[a] kcal/kg green, 1620 kcal/kg green and 4822 kcal/kg green respectively. A comparison of the specific energy consumption of downdraft kiln manufacturing stoneware crockery with a tunnel kiln and a shuttle kiln manufacturing similar products shows that the specific energy consumption of downdraft kilns is significantly higher than that of tunnel and shuttle kilns. Comparison of thermal efficiency shows that the thermal efficiency was 3.0% in downdraft kiln whereas it was 14.4% in tunnel kiln and 5.6% in shuttle kiln. In terms of operating fuel costs, the tunnel kilns are about 35% more efficient than tunnel kilns.

In addition, due to improper combustion control system, the percentage of rejects for downdraft kilns is at least 20% more than the tunnel kilns. Because of these advantages, it has been observed that a gradual shift from the traditional downdraft kiln technology to tunnel kiln technology is taking place in the Khurja pottery cluster. In fact no new downdraft kilns have been installed in the cluster in the recent past whereas, the number of tunnel kilns that have come up have increased many fold (chapter 2). As mentioned earlier, at present there are about 40 tunnel kilns in operation and around 40 more are under various stages of construction. It is expected that due to the market forces, within the next 2-3 years, all downdraft kilns will be closed down. This technological shift might be much faster as more and more local entrepreneurs set up tunnel kilns in the cluster, which would in turn convince other units for adopting tunnel kilns. Keeping in mind the rapid pace at which this shift is taking place, the other recommendations related to incremental improvements in energy efficiency of downdraft kilns through housekeeping and best operating practices have not been covered in this report[b].

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[a] The specific energy consumption was calculated based on the data taken for down draft kilns manufacturing stoneware crockery

[b] Earlier report by CGCRI, on 'Thermal energy conservation in conventional DD Kilns' gives some of the measures that can be implemented to improve the energy efficiency of downdraft kilns. The recommendations of this report are discussed in chapter 4

# 7

# Detailed strategy for implementation

This chapter outlines a strategy for upgradation and modernization of the cluster. The objective here is to formulate a strategy to reduce the energy consumption in the kilns, to increase productivity of the processes and to improve the quality of products manufactured in pottery units at Khurja.

The present study is done at a cluster level to understand the dynamics of interaction between various stakeholders and to pave way for meaningful technological intervention in the cluster. In this regard, TERI has kept close and detailed interaction with industry association (KPMA) and Pottery Development Office (PDO), Khurja throughout the project. The present study has helped in determining the present level of collective and individual technological capacity of firms in the cluster and identifying their technology needs.

Although technology demonstration is a major thrust area in the strategy for upgradation of the cluster, technology upgradation by itself is not sufficient to ensure growth and sustainability of the cluster. Other factors that influence the operation of units in Khurja are related to infrastructure. Infrastructure issues have been highlighted several times in various reports on the Khurja pottery cluster, but still the problems related to poor infrastructure persist in the cluster.

As a first step towards improving the operational efficiencies of the units in the cluster, uninterrupted and high quality power should be made available. As discussed earlier, this would result in higher electrical efficiency of the equipment, less breakdowns, less maintenance costs and higher productivity. Although an "industrial feeder" has been sanctioned for Khurja, it should be implemented without any further delay. Additional investments, which will be required for replacing transformers and upgrading other power distribution infrastructure, should also be made available at the earliest.

The condition of roads in the cluster needs to be improved to make various units more accessible. Improvement in the condition of roads will not only help in easy movement of material to the respective units but also help to project a better image of the cluster to prospective export clients.

## Options for technology demonstration

This section discusses various technology demonstration options in raw material processing and kilns. With regard to raw material preparation, major issues that are of relevance are related to better operating practices and/or use of better materials for the processes. As discussed in Chapter 5, the recommendations related to raw material preparation do not represent any technological changes requiring complementary investment in infrastructure/plant and equipment.

Due to market forces and pollution problems, the pottery units in Khurja are already adopting the oil fired tunnel/shuttle kilns. This is a positive development and a good sign for the long-term sustainability of the cluster. It is expected that in next two or three years all the units in Khurja will change over to oil fired shuttle/tunnel kilns. In the years to come, the market forces would make operation of down draught kilns unviable and therefore pottery units that are not able to change over to oil-fired kilns will gradually die down.

Since change over to energy efficient tunnel/shuttle kilns is already occurring in the cluster, therefore the implementation strategy focuses on various incremental technological improvements to enhance the performance of tunnel/shuttle kilns. As discussed elsewhere in the report, the tunnel kilns constructed in Khurja are based on the designs adapted from those of tunnel kilns used in Thangad cluster. After studying the performance of the kilns during energy audits, a number of incremental technological options have been identified for tunnel and shuttle kilns. These incremental innovations can be taken up for demonstration in an existing kiln or a new kiln can be set-up in one of the unit that will act as a role model for others to follow. Other house keeping measures in the kilns, such as provision of alarm for limiting temperature inside the kiln, optimizing burner operation, sealing of firing zone from cooling and preheating zones, etc. can be taken up alongside with the demonstration project in a particular unit.

For the purpose of demonstrating these incremental improvements, a detailed technology audit should be carried for an individual unit and if required, assistance could be taken from overseas consultants in the field of kiln design and ceramics. This will help in bringing finer ideas and a few more modifications that can be taken up for demonstration. To discuss the outcomes of this diagnostic study, a workshop was organized at Khurja involving participation from various stakeholder groups. The participants at workshop included senior members/office bearers of Khurja Pottery Manufacturers Association (KPMA), entrepreneurs, senior officials from the office of Development Commissioner, Small Scale Industries, Government of India, officials from Pottery Development Office, Khurja, representatives from local banks and project team members from TERI and Central Glass & Ceramic Research Institute, Khurja.

Various recommendations for improving the energy efficiency of kilns were presented and discussed in the workshop. It was decided to focus on incremental changes in technology to improve the energy efficiency of kilns. Senior officials from the office of Development Commissioner, Small Scale Industries also apprised the entrepreneurs about various schemes for technology modernization and ISO 9000 implementation in small-scale industries.

As an outcome of this workshop, the following options have been identified for technology demonstration in the cluster.

## *Reducing dead-weight of trolley in tunnel kiln*

The dead weight of trolley is an additional source for heat loss because the trolley mass is also heated to the firing temperature along with the products. The refractory bricks used in the trolley form about 65% of the dead weight of the trolley. Therefore, it is possible to reduce heat loss by reducing the dead weight of refractory material by about 30%. By implementing this recommendation, the ratio of weight of refractory material to the weight of greens can be brought down form existing 2 : 1 to about 1.5 : 1. The investment that is required for adopting this measure is minimal. By adopting this measure an annual energy savings of around Rs 1.6 lakh can be achieved.

| | | |
|---|---|---|
| Indicative investment | - | Rs 3.1 lakhs |
| Approximate energy savings/annum | - | Rs. 1.6 lakhs |
| Simple payback period | - | ~ 2.0 years |

## Use of decker plates in place of saggars in tunnel kiln

Replacement of existing stacking arrangement using saggars by decker plates will lead to increase in production, because more material can be stacked per unit volume. The production level is expected to increase by about 30% by using decker plates.

The up front investment required for changing over 30 trolleys with decker plates is expected to be around Rs 7.5. lakhs. Approximate savings in cost due to improved specific energy consumption and on account of manufacturing cost of saggars is expected to be around Rs 7.0 lakhs.

| | | |
|---|---|---|
| Indicative investment | - | Rs 7.5 lakhs |
| Approximate energy savings/annum | - | Rs. 7.0 lakhs |
| Simple payback period | - | ~1 year |

## Use of auto combustion control of burners in tunnel kiln

The existing burners in the tunnel kiln are operated manually. The oil flow to burners is regulated manually by the operator as per the temperatures prevailing inside the kiln. Any negligence on the part of the operator will not only cause over-firing or under-firing of the product, but also lead to higher energy consumption. To overcome this problem and to maintain a uniform temperature inside the kiln, it is recommended to use auto on-off burners. An automatic burner with ratio-controller, which switches on or off as per the temperature prevailing inside the firing zone, would help in avoiding such over/under firing leading to optimum fuel consumption. Though it is difficult to quantify the exact energy savings, TERI's experiences in small scale industrial furnaces show that substantial reduction (around 10%) in fuel consumption are possible. The investment required towards burner and control panels is Rs 3.5 lakhs.

| | | |
|---|---|---|
| Indicative investment | - | Rs 3.5 lakhs |
| Approximate energy savings/annum | - | Rs. 2.1 lakhs |
| Simple payback period | - | 1.7 years |

## Other housekeeping measures

Some other energy efficiency measures that can be implemented in tunnel kiln where the demonstration is given are mentioned below.

- Improved insulation of the kiln
- Sealing of firing zone from cooling and preheating zones
- Provision of inlet air filter for blower
- Use of baffle wall inside the kiln (implementation of this option will depend on the configuration of burners in the kiln of the demonstration unit)
- Optimisation of blower power (implementation of this option will depend on the configuration of the blower being used in the demonstration unit/s).

The measures can be implemented side-by-side while carrying out demonstration of other options in the selected unit(s). The investment that is required in implementing the above mentioned measures could vary depending upon the present state of the kiln in a unit(s), where demonstration is carried out. Total investment required for demonstration of these measures is expected to be about Rs 9.0 lakhs. Benefits can be realized in terms of reduced energy consumption, improvement in quality of finished product and lesser maintenance costs.

The final selection of the demonstration unit(s) would be done in consultation with the industry association for the second phase of the project.

## Capacity building of the entrepreneurs through focused training

It was evident during this study that most of the entrepreneurs in Khurja cluster lack information about various technological options. Ignorance about the new technologies and their benefits constrains the decision-making capacity of the entrepreneurs to upgrade the technologies. Moreover most of the workers and operators working in Khurja do not have adequate technical skills to operate and maintain the new technologies.

In view of the above, it is crucial that the capacity of the entrepreneurs is developed through focused training and proper information dissemination. Focused training should be carried out for improving the knowledge of the entrepreneurs regarding the importance of various issues related to raw material processing and kilns. Besides the training programs, information handbooks, highlighting the various aspects of raw material quality, raw material processing, energy conservation options in kilns, can be prepared and circulated to pottery units free of cost or at nominal charges.

Technical training should also be provided to the workers to upgrade their technical skills.

## Raw materials used in different Units:

| Unit | Body Processing | | | | | Glaze Preparation | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | Ahmedabad clay<br>Eklera clay | Than clay<br>Bhuj clay<br>Bikaner clay (B)<br>Chandia clay | Quartz<br>Potash feldspar<br>Pyrophyllite | | | Quartz<br>Marble/ Calcite<br>feldspar<br>Ahmedabad Clay | Red Iron Oxide<br>Magneese oxide<br>Chromium oxide<br>Barium Carbonate<br>Zinc Oxide | | |
| B | China Clays<br>Amrapali clay<br>Raj mahal clay(Pink)<br>Rajmahal clay (white) | Plastic Ball Clays<br>Bikaner Ball clay (white)<br>Bhuj clay<br>Than clay<br>Mudh clay<br>Bikaner clay (pink) | Non Plastic<br>Calcined QZ<br>Silica Sand<br>Potash Feldspar | Chem<br>Sodium Sand<br>Potash Feldspar | Aux<br>Plaster of Paris for moulds | Raw materials<br>Calcined Quartz<br>Potash Feldspar<br>Soda Feldspar<br>Marble T T.-75 | Chem<br>Zinc Oxide<br>Barium Carbonate<br>Zirconia<br>Different colouring agents | Frits<br>Opaque frit for opaque glaze | Opcifier<br>Zirconium Silicate |
| C | Amrapali<br>English India<br>TT - 75 | Bikaner clay | Quartz<br>Potash Feldspar | | Plaster of Paris | Feldspar<br>Quartz<br>Marble<br>Rajmahal (white) | Zinc oxide<br>Barium Carbonate | | |
| D | Ahmedabad Clay | Bhuj clay<br>Bikaner Clay<br>Than clay<br>Mudh clay | Quartz<br>Potash Feldspar | Sodium Silica | Plaster of Paris mould | Fridspar<br>Quartz<br>Marble<br>Ahmedabad clay | Barium Carbonate<br>Zinc Oxide<br>Red Iron Oxide<br>Black $MnO_2$<br>Chromium Oxide | | Zirconia |
| E | Rajmahal clay<br>English India<br>TT-75 | | Feldspar<br>Bone Ash | | Plaster of Paris | Feldspar<br>Quartz<br>Calcite<br>TT-75 | Barium Carbonate<br>Zinc Oxide | Transparent frit | |

Annexure 5.2

## Physical properties of china clays collected from units under survey

| Properties | Amrapali | Bhuj | Rajmahal Pink | English India | Rajmahal White | TT 75 | Ahmedabad |
|---|---|---|---|---|---|---|---|
| **Plastic Properties** | | | | | | | |
| 1. Residue on 45µ (%) | 0.6 | 12.6 | 0.2 | 0.45 | 0.24 | 0.25 | 0.5 |
| 2. Moisture content(%) | 1.5 | 1.5 | 1.4 | 1.5 | 1.5 | 1.4 | 1.7 |
| 3. Slaking nature | Moderate | Slow | Moderate | Moderate | Moderate | Very Quick | Moderate |
| 4. Atterberg No. | 13 | 9 | 12 | 14 | 17 | 4 | 11 |
| 5. Plasticity by hand | Good | Good | Good | Good | Good | Poor | Good |
| 6. Water of plasticity(%) | 27 | 33 | 30 | 40.3 | 36.11 | 36.59 | 34.70 |
| 7. Dry Shrinkage(%) | 3.95 | 3.19 | 3.95 | 5.26 | 3.41 | 4.39 | 11.21 |
| 8. Dry M.O.R.(kg/cm$^2$) | 19 | 9 | 13 | 9 | 18.21 | 6 | 25.5 |
| 9. Green color(dry) | White | White | Pinkish | White | White | Pinkish | Dull white |
| **Fired Properties** | | | | | | | |
| 1. Fired color at 1200°C | Light yellow | White | Light yellow | White | Creamish white | Clear white | Creamish white |
| at 1300°C | Light yellow | White | Light yellow | White | Creamish white | Clear white | Creamish white |
| 2. Fired M.O.R. at 1200°C | 113 | 211 | 187 | 147 | 116 | 105 | 125 |
| at 1300°C | 44.66 | 336 | 611 | 234 | 140 | 136 | 170 |
| 3. Water absorption(%) at 1200°C | 5.20 | 15.63 | 10.86 | 12.25 | 13.75 | 23.70 | 14.11 |
| at 1300°C | 1.29 | 6.57 | 5.22 | 6.23 | 7.81 | 15.21 | 6 13 |
| 4. Fired shrinkage(%) at 1200°C | 13.33 | 10.37 | 8.45 | 7.5 | 8.5 | 7.2 | 6.83 |
| at 1300°C | 13 63 | 14.28 | 11.11 | 12.2 | 11.20 | 9.6 | 10.80 |
| **Particle size distribution** | | | | | | | |
| >25µ | 2 | 14 | 2 | 2 | 2 | 2 | 3 |
| 25µ - 15µ | 2 | 3 | 4 | 3 | 2 | 2 | 2 |
| 15µ - 10µ | 7 | 4 | 7 | 5 | 4 | 3 | 6 |
| 10µ - 8µ | 3 | 2 | 4 | 4 | 3 | 4 | 3 |
| 8µ - 5µ | 3 | 5 | 6 | 11 | 6 | 5 | 5 |
| 5µ - 3µ | 10 | 5 | 9 | 11 | 9 | 8 | 8 |
| 3µ - 2µ | 1 | 1 | 5 | 7 | 5 | 7 | 7 |
| 2µ 1µ | 9 | 10 | 5 | 3 | 6 | 5 | 6 |
| <1µ | 63 | 53 | 58 | 54 | 63 | 64 | 60 |
| <2µ | 72 | 66 | 63 | 57 | 69 | 69 | 66 |
| <10µ | 89 | 79 | 87 | 90 | 96 | 89 | 89 |

Annexure 5.3

## Physical properties of plastic/ ball clays collected from units under survey

| Properties | Bikaner Pink | Than clay | Bikaner White | Chandia Clay | Mudh Clay |
|---|---|---|---|---|---|
| **Plastic Properties** | | | | | |
| 1. Residue on 45μ (%) | 5.3 | 12.5 | 4.0 | 3.0 | 0.5 |
| 2. Moisture content(%) | 2.5 | 1.2 | 3.0 | 1.5 | 2 |
| 3. Slaking nature | Very quick | Moderate | Moderate | Very slow | Slow |
| 4. Atterberg No. | 16 | 6 | 21 | 6 | 20 |
| 5. Plasticity by hand | Very good | Poor | Good | Moderate | Very Good |
| 6. Water of plasticity(%) | 32 | 26 | 26 | 25.8 | 36.67 |
| 7. Dry Shrinkage(%) | 5.26 | 5.70 | 5.27 | 4.16 | 6.12 |
| 8. Dry M.O.R.(kg/cm$^2$) | 31 | 19 | 10 | 61 | 34.21 |
| 9. Green colour(dry) | Light gray | Black | Gray | Blakish | Dull white |
| **Fired Properties** | | | | | |
| 1. Fired colour at 1200°C | White | White | Dark cream | White | Cream |
| at 1300°C | White | White | Dark cream | White | Dull white |
| 2. Fired M.O.R. at 1200°C | 138 | 302 | 616 | 323 | 685 |
| at 1300°C | 209 | 169 | 755 | 407 | 810 |
| 3. Water absorption(%) at 1200°C | 6.5 | 17.51 | 7.09 | 17.45 | 4.2 |
| at 1300°C | 1.0 | 15.74 | 0.62 | 15.98 | 0.85 |
| 4. Fired shrinkage(%) at 1200°C | 13.25 | 3.41 | 8.57 | 3.62 | 8.7 |
| at 1300°C | 16.41 | 4.27 | 10.74 | 3.41 | 9.46 |
| **Particle size distribution** | | | | | |
| >25μ | 4 | 25 | 3 | 2 | 8.5 |
| 25μ - 15μ | 1 | 8 | 3 | 2 | - |
| 15μ - 10μ | 1 | 10 | 7 | 11 | 3 |
| 10μ - 8μ | 1 | 5 | 3 | 7 | 3 |
| 8μ - 5μ | 1 | 7 | 6 | 13 | 7 |
| 5μ - 3μ | 7 | 8 | 10 | 11 | 8 |
| 3μ - 2μ | 5 | 3 | 4 | 4 | 5 |
| 2μ - 1μ | 5 | 2 | 10 | 13 | 80 |
| <1μ | 75 | 32 | 54 | 37 | 52 |
| <2μ | 80 | 34 | 64 | 50 | 60 |
| <10μ | 94 | 57 | 87 | 85 | 82.5 |

Annexure 5.4

# Chemical analysis of the samples received from different units

| Sample | LOI | SiO2 | Al203 | Fe203 | TiO2 | CaO | MgO | Na20 | K20 | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Amrapali (M) | 13.93 | 47.26 | 35.13 | 0.20 | 0.31 | 1.40 | 0.35 | 0.67 | 0.27 | - | 99 52 |
| Ahmedabad Clay | 14.84 | 44.64 | 34.94 | 1.34 | 1.14 | 1.67 | 0.97 | 0.10 | 0.16 | - | 99 80 |
| Rajmahal Clay(pink)(M) | 13.12 | 46.68 | 35.29 | 1 90 | 0.89 | 0.28 | 0.50 | 0.60 | 0.28 | - | 99 54 |
| Rajmahal Clay(white) (M) | 12.60 | 48.90 | 34.51 | 1.71 | - | 0.67 | 0.20 | 0.51 | 0.41 | - | 99 51 |
| Bhuj Clay(M) | 13.93 | 42.89 | 37.34 | 1.09 | 1.90 | 0.70 | 1.00 | 0.68 | 0.45 | - | 99.98 |
| Bikaner (M) Clay (pink) | 12.38 | 52.24 | 31.33 | 1.02 | 1.71 | 0.42 | 0.50 | 0.16 | 0.20 | - | 99 96 |
| English Ind China clay (C) | 14.18 | 44.98 | 38.30 | 0 60 | 0.22 | 0.26 | 0.28 | 1.11 | 0.04 | - | 99 98 |
| TT-75 (S) | 13.65 | 49.04 | 36.24 | 0.11 | 0.03 | 0.25 | 0.01 | 0.42 | 0.23 | - | 99 98 |
| Mudh Clay (K) | 10.17 | 57.19 | 27.93 | 1.19 | 1.17 | - | 0.60 | 0.70 | 1.00 | - | 99 95 |
| Than Clay(M) | 13.36 | 59.22 | 23.44 | 0.82 | 1.18 | 0.42 | 0.40 | 0.42 | 0.15 | - | 99 41 |
| Chandia Clay (N) | 9.44 | 60.60 | 25.50 | 1.00 | 1.20 | 0.72 | 0.52 | 0.25 | 0.63 | - | 99 86 |
| Silica Sand (M) | 0.50 | 98.24 | 0.25 | 0.04 | - | 0.56 | 0.30 | 0.06 | 0.02 | - | 99 97 |
| Quartz Gl (M) | 0.10 | 99 74 | - | - | - | 0.14 |  | - | - | - | 99 98 |
| Pyrophyllite (N) | 4.70 | 46 52 | 35.96 | 1.24 | - | 0.81 | 0.65 | 0.44 | 9.64 | - | 99 96 |
| Bone Ash (S) | 2.17 | 8 57 | 0.48 | 0.08 | - | 49.02 | - | - | - | P2O5 39.65 | 99 97 |
| K-Feldspar Gl. (M) | 0.32 | 63.57 | 18.61 | 0.24 | - | - | 0.20 | 4.01 | 12.48 | - | 99 43 |
| Marble (M) | 43.44 | 0.16 | - | - | - | 56.00 | - | - | - | - | 99 60 |
| Zirconia | - | 35.07 | 2.58 | 0 19 | - | - | - | - | - | 57.57 ZrO2 | 95 41 |
| BaCO3 (M) |  | - | - | - | - | - | - | - | - | BaCO3 97 54 | 97 54 |
| ZnO(M) |  | - | - | - | - | - | - | - | - | ZnO 99 48 | 99 48 |
| GPOG |  |  |  |  |  |  |  |  |  |  |  |
| Chandia fired | - | 67 02 | 28 20 | 1 10 | 1.33 | 0 80 | 0.57 | 0.27 | 0.70 | - | 99 99 |
| Than fired |  | 68.82 | 27.24 | 0 95 | 1 36 | 0.48 | 0.46 | 0 49 | 0 17 | - | 99 95 |
| Bikaner fired | - | 59 65 | 35 77 | 1 16 | 1 95 | 0.48 | 0 57 | 0 17 | 0 23 | - | 99 99 |

Annexure 5.5

## List of Raw - Material Suppliers

RAJMAHAL QUARTZ SAND
& KAOLIN CO.,
1, Netaji Subhash Road,
Calcutta – 700 001.

R.C. JAIN
C/o MAHAVIR MINERALS CO.,
Rajeswari Road, Minerals &
Refractory, Shivpuri – 473 551
Shivpuri (M.P.).

SHRI R.D. PLASTER
INDUSTRIES
Sri Mahesh Goyal
29-30 F, Indl. Area (Rico)
Nohar – 335 523
Ph. – (01555) 21328

SAHAJ CERCHEM (P) LTD.,
47, Vijay Nagar Colony (Old)
Agra – 282 004.

S.R. PLASTER (Sri R. K. Udsaria)
H-1, 258-269, Indl. Area (Riico)
Sardarshahr – 331403.
Ph. (01564) 20808 (F), 30646 (R)

RAJSHREE MINERAL &
CHEMICALS
Chandra Market, Out Side, Ajmeri
Gate
Beawar (Rajasthan).
Ph. – 01462 – 21457.

RAJ MINERALS (Sri Jayesh
Mehta)
Survey No.-15/1, Phase-1
Near Ambuja Ceramics Pvt. Ltd.,
National Highway No. – 8 A
Bhanchan, (Kutch)- 370 140
Ph. – (02837) 22306/7(O), 22297, -
858(R)

S V M TEA & INDUSTRIES LTD.,
Sri K. C. Verma, Sales Executive
4802/B, GIDC Estate
Ankleshwar = 393 002 (Gujrat)
Ph. – (02646) 24686, Fax 24373.

COSSIM BAZAR CHINA CLAYS
MINES (P) LTD.,
138, Biplabi Bihari Basu Road,
3rd Floor, P.B.No. – 353,
Calcutta – 700 001.
Ph. – 25 – 6348, 25 - -418.

ABREF PVT. LTD.,
(Sri N.G. Manmohan, Director)
F-17, Sipcot Complex
Gummidipundi-601201. (T.N.).
Ph. -(044) 835852(O) 6425527 (R)

GAJANAN MINERALS (P) LTD.,
B-47, 1st Phase, Indl. Area,
Adityapur
Jameshedpur – 832 109.
Ph.-87696(W) / 87191 (R)

MANAN CERAMIC COLOURS
(Sri M.L. Patel)
D-35 A, Diamond Park, G.I.D.C.,
Naroda
Distt. – Ahmedabad – 382 375(Guj).
Ph. – 2841336 / 7452576

RAJ PLASTERS PVT. LTD.,
17, Indl. Area, Bikaner – 334
001(Raj.).
Ph. 4213, 4313

POOJA ENTERPRISES
3/9, A, Udyog Mandil, No-1.7-C,
Pitamber Lane

Mahim (West), Mumbai – 400 006.
Ph. 4440003, 4457496.

PEARL – JET MICRONS (P) LTD.,
(Sri P.C. Chopra, Director)
Old Lane, Near Post Office,
Ganga Shahar – 334401, Bikaner
Ph.-(0151) 200954, 541502.

SUKASO CERACOLOURS (P)
LTD.,
(Sri D.V. Ramachander Rao, Mktg.
Man.)
1275, Road No. 63A, Jubilee Hills,
Hyderabad – 500 003.
Fax.-(040)-247859

THE RAJASTHAN MINERALS
BIKANER REFRACTORIES
99-100 Indl. Area, Road No.-9,
Rani Bazar
Bikaner – 334 001 (Raj.).

WINDSOR CERAMIC IND.
C-210, Sarodaya Enclave,
New Delhi – 110 017.
Ph. – 6524198, - 6126

BHARAT MINERALS SUPPLY
CORPN., Lodha Dharmashala
Prathviraj Marg, P. Box No.- 61
Ajmer (Rajasthan)

ENGLISH INDIA CLAYS LTD.,
Veli – 695021, Kerla
Thirvananthapuram

BHALLA CHEMICALS WORKS
PVT. LTD.,
Daulta Bad Road,
Gurgaon – 122 001 (Haryana)

DAGA MINERALS
Bagri Mohalla,
Bikaner (Rajasthan)

EKLERA CHINA CLAY WORKS
Eklera – 383 225, Tq. Idor
Sabarkantha, Gujrat

EASTERN MINERALS,
195, Laxman Ganj, Gwalior Road,
Jhansi (U.P.).

APEX MINERAL COMPANY
Station Road, Rajgarh (Alwar)-
301408
Rajasthan (India)
Phone-Alwar-20714, Rajgarh-46

ASHWAIN & CO.,
25, Bram Shatriya Society
Ellis bridge, Ahmedabad – 380 006.

AGRAWAL MINERALS
(Sri Sunil Agrawal)
F-34, Riico Indl. Area)
Parbhatpura, Ajmer (Raj.).
Ph.-441690, - 843(O), 441701,-
2700(R)

AMRALI & COMPANY
289, New Cloth Market
Ahmedabad – 380 002.
Phone – 079 – 361253, 365851.

JAICHAND LAL DAGA
Bagree Mohall,
Bikaner – 334 001.
Phone – 5944

F.M. SHAH MINERALS
P.O. Than Garh (Gujrat)

MODI MINERAL & GRINDING
MILLS (P) LTD.,
Nim-Ka-Thana – 332 713(Raj).

MANGALAM MINERALS
Terapanth Sabha Bhawan
Teliyanchopar
Mebadi Bazar, Beawar-
305901(Raj.).

Ph. - (01462) 21457

K. G. MINES & MINERALS
Ashram Chura, Jassusar Gate
Bikaner (Rajasthan)
M. L. DAGA
100 Ratan Kunj, Adarsh Nagar,
Ajmer Road,
Beawar (Rajasthan)

ORIENTAL TALC PRODUCTS
PVT. LTD.,
10, Industrial Area
Dahod Road,

RAJ PLASTER PVT. LTD.,
17/18, Industrial Area
Bikaner - 334 001 (Raj.).
Ph. - 4213

RAJASTHAN MINERALS
SUPPLY CORPN.,
Near Rly. Station, P.O. Sanod
Alwar (Rajasthan)

SHRI MODI LEVIGATED
KAOLIN
PVT. LTD.,
Neemka Thana - 332 713 (Raj.).
Ph. - 2081, 2038, 2017.

SOMPURA CERAMIC
INDUSTRIES
Main Road
P.O. Than Garh (Gujrat)
Banswara - Rajasthan

PRATAPPURA MINERALS
INDUSTRIES
244, Civil Lines
Jhansi (U.P.).

Annexure 5.6

## Price list of raw materials at Khurja

| Raw Materials | Cost (Rs./kg) |
|---|---|
| I China clays | |
| 1. Bhuj clay | 2.10 |
| 2 Amrapali | 3.20 |
| 3 TT-75 | 4 00 |
| 4 English India | 6.50 |
| 5. Rajmahal (Pink) | 2.80 |
| 6 Rajmahal(white) | 6.00 |
| 7 Ahmedabad clay (Eklehara)-I | 3.00 |
| (Eklehra )- II | 2.60 |
| II Ball / Plastic clay | |
| 1. Than | 1.80 |
| 2 Bikaner(white) | 1.10 |
| 3. Bikaner (pink) | 1.10 |
| 4. Mudh | 1.25 |
| 5 Chandia | 1.10 |
| III Non plastic | |
| 1 Quartz | 1.25 |
| 2 Silica sand | 1 10 |
| 3 Feldspar | 1.30 |
| 4 Feldspar (Powder) #200 | 1.40 |
| 5 Pyrophyllite | 1.00 |
| 6. Bone ash | 1.60 |
| IV. Chemical & other raw materials | |
| 1 Zinc oxide | 64 00 |
| 2 Barium carbonate | 26 00 |
| 3 Marble / calcite | 1.20 |
| 4 Zircon | 38.00 |
| 5. Chromium oxide | 160.00 - 188 00 |
| 6 Iron oxide | 8.00 |
| 7 Manganeese dioxide | 3.00 - 25 00 |
| 8 Alumina powder | 25.00 |

**Annexure 5.7**

# The details of process in summarized

| Operations for fabrication | A | B | C | D | E |
|---|---|---|---|---|---|
| Jiggering | | | | | 2 Roller |
| No. of Jigger Jolly | 12 | 9 | 12 | 14 | Jolly |
| No. of moulds used/- | --- | 1000 | 1200 | 600 | 2 |
| Item/ day | | | | | |
| Water of absorption of the | | | No Physically | | |
| moulds | | | seen | | |
| | | | 20-40 | | |
| | 5.6 | 100 | | ~ 240 | 80-100 |
| Cycles used | | | | | |
| Time required to take out the | | Summer 2 hrs | | | |
| green ware | | Winter 3 hrs. | | Summer 20-30 | |
| | | | | min. | 2-3 min. |
| | | | | Winter 1.5 hr | |
| | | 2000 | | | |
| Drying or finishing/ day/ person | Making 4800 | | 1000 | 2500 | |
| | Finishing 3000 | | | | 3000 |
| | ~ 10% | | | | |
| Shrinkage of the ware | Not noticed | ~ 11% | Not noticed | ~ 10% | |
| Warpage | Yes | Yes | | Yes, 2-4% | ~ 14% |
| Cracks | | Yes | " | Yes, 2-4% | ~ 5-8% |
| | | | " | | ~ 5% |
| Casting | | | | Handle | |
| Quantity of Body | | | | | |
| Type & quantity of electrolyte | | 100 Kg | | 3-4 Tons/month | |
| | | Soda - 300 gm | 400-500 Kg/ | Soda-5 Kg | 1 Kg. |
| Water | | Silicate - 150 | day | Silicate-2.5Kg | Sodium |
| | | gm | Soda -10 Kg | per | Hexa meta |
| | | | Silicate- 5Kg | Kg. | Phosphate |
| | | | Per 100 Kg. | | |

Annexure 5.8

## Size of Mill vs. size of Pebbles

| Diameter of Mill | | Size of Pebbles | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Feed size | 1" | $1^1/_2$" | 2" | $2^1/_2$" | 3" | $3^1/_2$" | 4" |
| 1' | $^1/_2$" | 80% | - | 20% | - | - | - | - |
| 2' | -do- | 40% | 40% | 20% | - | - | - | - |
| 3' | -do- | 35% | 35% | 15% | 15% | - | - | - |
| 4' | -do- | - | 35% | 35% | 15% | 15% | - | - |
| 5' | -do- | - | - | 40% | 40% | 20% | - | - |
| 6' | -do- | - | - | - | 40% | 40% | 20% | - |
| 7' | -do- | - | - | - | 40% | - | 40% | 20% |

## Size of Mill vs. Quantity of Water

| Diameter of Mill (Sq Ft.) | Internal Capacity lit (approx ) | Material (kg) | Pebble (kg) | Water (lit.) | Power (h p.) |
|---|---|---|---|---|---|
| $1^1/_2$" x $1^1/_2$" | 25 | 9 | 18 | 4 5 | 1-1 5 |
| 2 x 2 | 80 | 30 | 60 | 15 | 2-3 |
| $2^1/_2$" x 3 | 230 | 80 | 160 | 40 | 3-5 |
| 3 x 3 | 350 | 125 | 250 | 63 | 5-7 5 |
| 3 x $3^1/_2$" | 510 | 180 | 360 | 90 | 5-7.5 |
| 4 x $4^1/_2$" | 1040 | 370 | 740 | 185 | 10 |
| 5 x 5 | 1725 | 600 | 1200 | 300 | 12.5 |
| 6 x 6 | 2925 | 1050 | 2100 | 525 | 25 |
| 7 x 7 | 5000 | 1750 | 3500 | 875 | 25 |

## Annexure 5.8A

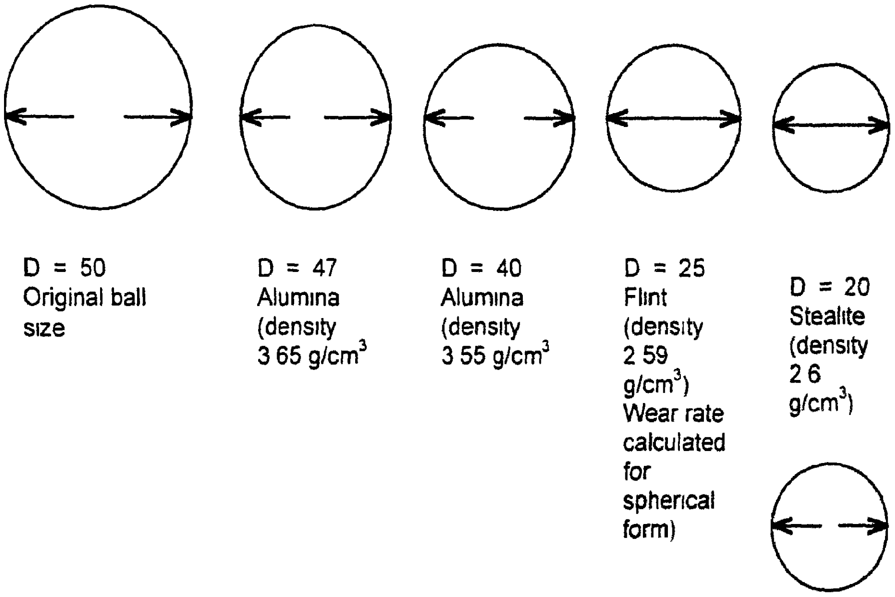

D = 50
Original ball size
D = 47
Alumina (density 3 65 g/cm3
D = 40
Alumina (density 3 55 g/cm3
D = 25
Flint (density 2 59 g/cm3) Wear rate calculated for spherical form)
D = 20
Stealite (density 2 6 g/cm3)
D = 10
Porcelain (density 2 5 g/cm3)

**Figure 1** Wear rates for different grinding elements measured in a procelain slurry (extrapolated to 1000 h)

Annexure 5.9

## Defects in body and glaze and their remedies

Some common defects are encountered during the manufacturing of crockeries. The defects developed before firing, their cause and probable remedial measures are discussed below.

### Defects from body

| Defects | Cause | Probable Remedial measure |
|---|---|---|
| a. Cracks. | Excessive shrinkage | Reduce % of plastic clays |
| | Uneven drying | Slow drying |
| | Too soft or too hard cast for cast articles | Control rheological properties (fluidity, thixotropy etc. of the casting slip and casting time in moulds. |
| | Incomplete draining of slip | Proper draining out of excess slip from the moulds. |
| | Sticking to the plaster of paris moulds | Fine talcum powder to be applied on the inner mould surface before casting |
| | Seam / Joining Cracks | Joining by thicker slip, Thickning may be done by addition of about 0.1% $MgSo_4$ solution. |
| | Poor moulds release | Releasing of the piece to be done carefully. Poor release may be due to wet mould or bad quality of Plaster due to less shrinkage of the cast |
| b) Warpage | Defective plaster of Paris mould | Reject the mould |
| | Defective setter for placement of wares for casting | Replace by a proper one. |
| | Excessive shrinkage | Reduce the % of Plastic clay |
| | Uneven drying | Slow drying. For thick articles |
| | Releasing from the mould when the mould when the piece is too soft | More releasing time, releasing to be done carefully |
| | Slaking / Jerking during release | Avoid. Slaking / Jerking |
| c) Blisters & Pinholes | Air entrapping during blunging | Sufficient blunging time to remove entrapped air. |
| | Air entrapping due to faulty operation of slip pump | Rectify the defect in the pump and arrangement to remove air from supply |
| | Dusty mould or oil on the surface on the ware | Before casting/jiggering, remove dust by clean water from the mould and remove oil from the surface of the ware before glazing |
| | High viscosity of casting slip | Reduce viscosity of slip by adding water / soda silicate on suitability. |
| | Presence of mica in the body | Remove micaceous materials from composition |
| | Presence of Plaster of Paris particles | Reject the too-old plaster of Paris mould and control finishing operation of the wares and remove the plaster of Paris particles. |
| | Too fast and turbulent pouring of slip | Pour slowly and in an uniform speed. |

| Defects | Cause | Probable Remedial measure |
|---|---|---|
| | High concentration of soluble salt in the slip | Add small amount of BaCO3 during slip preparation (0.1-0.15%) |
| d) Crawling | Oil or greasy ware surface | Remove by finishing |
| | Presence of sharp corners in the ware | Finish by making the corners round |

## Defect from Glaze

| Defects | Cause | Probable remedial measures |
|---|---|---|
| a) Pinholes & Blisters | Fermentation of the organic binder / adhesive added in the glaze due to long storage | A few drops of anti-fungal agent (carbolic acid, Sodium phenate, oil of winter green, formaldehyde etc) may be added |
| | Chemical decomposition of carbonates etc. while the glaze slip is in storage | Avoid long storage |
| | Flat dipping, entrapping air in between the layer of glaze slip and the body | Avoid flat dipping |
| | Too violent dipping / spraying | Apply slow process |
| | Too long interval between application of successive coats | Interval to be reduced |
| | Differential shrinkage of a very thick glaze coat | Avoid thick glazing |
| | Excessive fine grinding of the glaze | Glaze to be ground up to 300#<br>(~0.5 - 1.0% residue) |
| b. Crawling | Non-adherence of the glaze to the body | Increase plastic clay in the glaze Binder (~ 0.1%) may be used. |
| | Too fine grinding of the glaze | Avoid too fine grinding |
| | Thick application of glaze | Use moderately thick glaze |
| | Presence of too much plastic clay | Reduce the % of plastic clay |
| | Presence of un calcined ZrO and in higher amount | Reduce % of ZnO and to be added in the Calcined form |

Annexure 5.9A

## Routine tests for raw material

| Raw material | Tests | Expected Result |
|---|---|---|
| I. China Clays | 1. Fired colour, fusibility by Button Test at the working temperature | White fired colour, non-fusible and free foreign material, specks and patches |
| | 2. Slaking nature | Quick |
| | 3 Fineness % wt (residue on 325#) | 1.5 |
| | 4 Plasticity by hand feel | Moderate - poor |
| | 5. Castability | Good casting slip with electrolyte concentration, Silicate addition 0.3-0.5 wt. %, casting thickness 10-12 mm / hr. |
| | 6. Absence of carbonates (Ca, Mg etc.) in dil HCL (1 1) | No effervescence of $CO_2$ gas. |
| II Ball clay | 1 Fired colour, fusibility by Button Test at the working temperature | Buff fired colour, Sintered but not fused and free from foreign materials, specks and patches. |
| | 2. Slaking nature | Moderate to slow |
| | 3. Fineness % wt. (residue on 325#) | 2-3, but for washed than clay 5-6 wt. % |
| | 4. Plasticity by hand feel | Very good – good |
| | 5 Castability | Fairly good casting slip with electrolyte concentration, silicate addition 0.4-0.8 wt. %. Casting thickness 6-8 mm / hr |
| | 6 Absence of carbonate (Ca,Mg etc) in dil HCL (1 1) | No effervescence of $CO_2$ gas |
| III Quartz / Silica Sand | 1 Fired colour Fusibility by Button Test at the working temperature | White - fired colour, should fuse nicely in to a clear glass mass free from foreign materials, specks and patches |
| | 2 Absence of Carbonate (Ca, Mg etc) in dil HCL (1 1) | No effervescence of $CO_2$ gas. |

| Raw material | Tests | Expected Result |
|---|---|---|
| IV. Potash<br>Feldspar/Soda Feldspar | 1. Fired colour, fusibility of 30# by Button Test at the temperature.<br>2. Absence of Carbonate (Ca, Mg etc) in dil HCL (1:1) | White - fired colour, should fuse nicely into a clear glass mass, free from foreign materials, specks and patches.<br>No effervescence of $CO_2$ gas. |
| V. Fire clay | 1. Fired colour, fusibility by Button. Test at the working temperature<br>2. slaking nature<br>3. Plasticity by hand feel<br>4. Absence of Carbonate (Ca, Mg etc) in dil HCL (1:1) | Buff fired colour, no sintering / fusion at the working temperature, should be free from foreign materials like mica, quartz particles and other fritty and fluxy impurities.<br>Moderate - slow<br>Very good<br>No effervescence of $CO_2$ gas. |
| VI. Chemicals.<br>A. Zinc Oxide | 1. Fired colour, fusibility by Button Test at the working temperature<br>2. Absence of Carbonates (Ca, Mg etc) in dil HCL (1:1) | White - buff fired colour, sintering / fusion noticed, free from foreign materials specks & patches<br>No effervescence of $CO_2$ gas |
| B. Barium Carbonate | 1. Fired colour, fusibility by Button Test at the working temperature<br>2. Presence of Carbonates in dil HCL (1:1) | White - buff fired colour, sintering / fusion noticed, free from foreign materials specks & patches<br>effervescence of $CO_2$ gas |
| C. Zircon Opacifier | 1. Fired colour, fusibility by Button Test at the working temperature<br>2. Absence of Carbonates (Ca, Mg etc.) in dil HCL (1:1) | White buff fired colour, no sintering / fusion, free from foreign materials specks and patches.<br>No effervescence of $CO_2$ gas |

Annexure 5.9/B

# Laboratory tests for Raw-material

| Raw material / Chemical | Tests as per IS - 2400 : 1965 | Expected Result |
|---|---|---|
| I. China Clays | • Dry Linear Shrinkage (at 110°C) %, Max. | 8.0 |
| | • Green Strength (Kg/cm$^2$), Min. | 10.0 |
| | • Particle Size finer than 10 u, %, Min | 70.0 |
| | • Fired shrinkage at working temperature, %, Max. | 18.0 |
| | • Water absorption of fired mass, fired at the working temperature, %, Max. | 12.0 |
| | • Loss on Ignition %, min. | |
| | • $Al_2O_3$ % by wt., min. | 12.0 |
| | • $Fe_2O_3$ % wt., Max | 34.0 |
| | • (Fe2O3 + TiO2) % by wt., max. | 1.0 |
| | • CaO % by wt., max. | 1.5 |
| | | 1.0 |
| II. Ball / Fire clay | • Dry Linear shrinkage (at 110°C) %, max. | 10.0 |
| | • Green strength (Kg/cm$^2$), min. | 35.0 |
| | • Particle Size coarser than 25 u, max | 15.0 |
| | • Fired shrinkage at the working temperature, % mass | 10.0 |
| | • Water absorption of fired bar, fired at the working temperature, % wt, max. | 7 0 |
| | • Loss on Ignition, % wt., min. | |
| | • $Al_2O_3$, % wt., min | 10.0 |
| | • $Fe_2O_3 + TiO_2$, % wt. max | 25 0 |
| | • CaO, % wt. Max | 2.75 |
| | | 1.0 |
| III. quartz / Silica Sand | • Silica ($SiO_2$), % wt, min | 97.0 |
| | • $Fe_2O_3$, % wt, max | 0.5 |
| | • CaO, % wt. Max. | 0.5 |
| IV. Potash Feldspar<br>Test as per IS<br>IS 9749 1981 | • $SiO_2$, % wt., max. | 67.0 |
| | • $Al_2O_3$, % wt. | 17 0-20 0 |
| | • $K_2O$, % wt, min | 10.0 |
| | • $Na_2O$, % wt., max | 4 0 |
| | • $(K_2) + Na_2O)$ % wt, min | 13 0 |
| V Zinc Oxide | Insoluble residue %, max. | • - 1 5 |
| (Purity test) | Zinc Oxide, purity % min | 98.5 |
| VI Barium Carbonate | Insoluble residue, % max | • - 1.5 |
| (Purity test) | $BaCo_3$, 5 min | 70 5 |
| VII Zircon Opacifier | $SiO_2$, %, max | 33.0 |
| (Purity Test) | $ZrO_2$, % min | 65.0 |

The above tests may help to improve the quality of products.

## Annexure 6.1

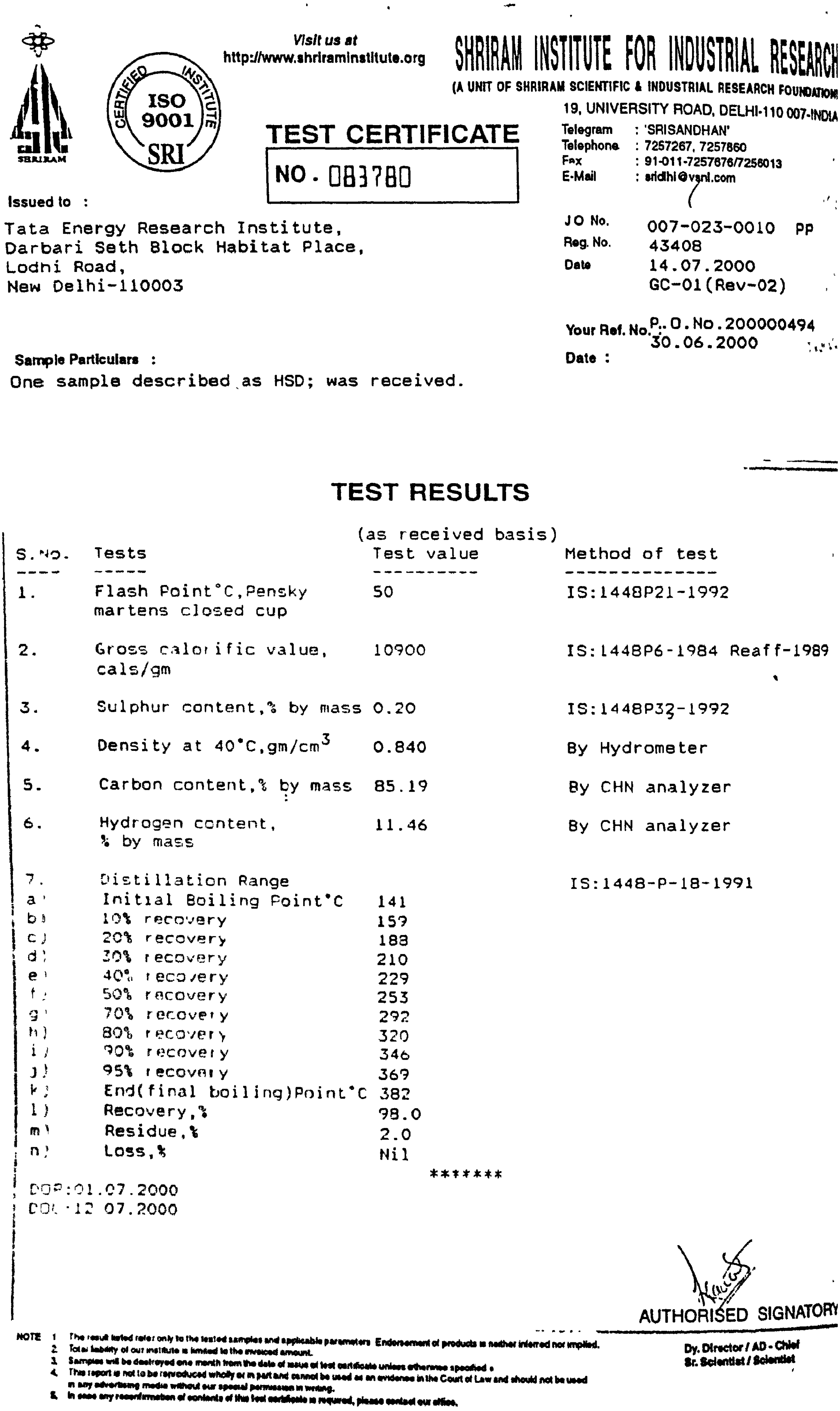
## Raw materials used in preparation of greens

| Raw material | Fraction (% by weight) | |
|---|---|---|
| | Tunnel | Shuttle |
| Feldsper | 18.9 | 25.0 |
| Quartz | 26.4 | 25.0 |
| Bikaner pink clay (plastic) | 18.9 | - |
| Bhuj clay | 13.2 | - |
| Than clay | 11.3 | - |
| Amrapali china clay (TT-75) | 7.5 | - |
| Rajmahal clay | 3.8 | - |
| China clay | - | 30.0 |
| Ball clay | - | 20.0 |
| Total | 100.0 | 100.0 |

## Ultimate composition of body material on wet basis (greens)

| Component | Fraction (% by weight) | |
|---|---|---|
| | Tunnel | Shuttle |
| $SiO_2$ | 61.10 | 67.0 |
| $Al_2O_3$ | 29.10 | 20.4 |
| $TiO_2$ | 1.50 | 1.0 |
| $Fe_2O_3$ | 1.00 | 0.7 |
| $Na_2O$ | 0.28 | 2.0 |
| $K_2O$ | 0.28 | 1.5 |
| MgO | 0.47 | 0.4 |
| CaO | 0.47 | 1.2 |
| Loss of ignition | 5.75 | 5.7 |
| Total | 100.00 | 100.0 |

## Annexure 6.2



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E-Mail : sridhi@vsnl.com

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Lodhi Road,
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JO No. 007-023-0010 PP
Reg. No. 43408
Date 14.07.2000
GC-01(Rev-02)

Your Ref. No. P.O.No.200000494
Date : 30.06.2000

**Sample Particulars :**
One sample described as HSD; was received.

### TEST RESULTS

| S.No. | Tests | (as received basis)<br>Test value | Method of test |
|---|---|---|---|
| 1. | Flash Point°C, Pensky martens closed cup | 50 | IS:1448P21-1992 |
| 2. | Gross calorific value, cals/gm | 10900 | IS:1448P6-1984 Reaff-1989 |
| 3. | Sulphur content,% by mass | 0.20 | IS:1448P33-1992 |
| 4. | Density at 40°C,gm/cm$^3$ | 0.840 | By Hydrometer |
| 5. | Carbon content,% by mass | 85.19 | By CHN analyzer |
| 6. | Hydrogen content, % by mass | 11.46 | By CHN analyzer |
| 7. | Distillation Range | | IS:1448-P-18-1991 |
| a) | Initial Boiling Point°C | 141 | |
| b) | 10% recovery | 159 | |
| c) | 20% recovery | 188 | |
| d) | 30% recovery | 210 | |
| e) | 40% recovery | 229 | |
| f) | 50% recovery | 253 | |
| g) | 70% recovery | 292 | |
| h) | 80% recovery | 320 | |
| i) | 90% recovery | 346 | |
| j) | 95% recovery | 369 | |
| k) | End(final boiling)Point°C | 382 | |
| l) | Recovery,% | 98.0 | |
| m) | Residue,% | 2.0 | |
| n) | Loss,% | Nil | |

*******

DOP:01.07.2000
DOC:12.07.2000

AUTHORISED SIGNATORY
Dy. Director / AD - Chief
Sr. Scientist / Scientist

NOTE
1. The result listed refer only to the tested samples and applicable parameters. Endorsement of products is neither inferred nor implied.
2. Total liability of our institute is limited to the invoiced amount.
3. Samples will be destroyed one month from the date of issue of test certificate unless otherwise specified.
4. This report is not to be reproduced wholly or in part and cannot be used as an evidence in the Court of Law and should not be used in any advertising media without our special permission in writing.
5. In case any reconfirmation of contents of this test certificate is required, please contact our office.

Annexure 6.3

# Colour of temperature

The colour inside the kiln is a good indicator of temperature. The operators in most of the small scale industries normally look at the colour to judge the temperature inside the kilns. Temperature indicators are generally not used in down draught kilns. However, with the advent of tunnel and shuttle kilns which are superior in terms of design, firing and fuel used, industries have slowly started using temperature indicators for the measurements. Table below shows the colour of temperature for different ranges.

| Colour of temperature | Temperature range (°C) |
|---|---|
| Lowest visible red | |
| – Night time | 470 |
| – Daylight | 550-650 |
| Dark red – bright cherry red | 650-750 |
| Cherry red – bright cherry red | 750-815 |
| Bright cherry red – orange | 815-900 |
| Orange – yellow | 900-1090 |
| Yellow – light yellow | 1090-1315 |
| Light yellow – white | 1315-1540 |
| White – bluish white | 1540 |

Annexure 6.4

# Heat balance of shuttle kiln

Heat input

HSD consumption = 427 lit/batch (359 kg/hr)
GCV of HSD = 10900 kcal/kg
Heat input = 3910920 kcal/batch

(1) Heat loss due to evaporation of moisture in greens = 39578 kcal/batch (1.0%)

(2) Reaction heat

Heat absorbed during heating up = 390615 kcal/batch
Heat released during cooling = 211744 kcal/batch
Heat absorbed during chemical reaction = 178871 kcal/batch (4.6%)

(1) Structural loss

As discussed, structural loss increases during heating cycle and reduces during cooling cycle. The heat losses were measured during heating cycle. It is assumed that, during cooling cycle, heat loss occurs at the same rate.

(a) Right surface

| Hour | Surface | Surface temperature ($^{o}$C) | Heat loss (kcal/batch) |
|---|---|---|---|
| Hour-1 | Ceramic fibre | 29 | - |
| | Brick structure | 29 | |
| Hour-2 | Ceramic fibre | 36-38 | 6636 |
| | Brick structure | 35-39 | |
| Hour-3 | Ceramic fibre | 39-42 | 9750 |
| | Brick structure | 41-51 | |
| Hour-4 | Ceramic fibre | NA | 13981* |
| | Brick structure | | |
| Hour-5 | Ceramic fibre | 47-57 | 18213 |
| | Brick structure | 39-67 | |
| Hour-6 | Ceramic fibre | 64-76 | 33620 |
| | Brick structure | 42-106 | |
| Hour-7 | Ceramic fibre | 71-90 | 47053 |
| | Brick structure | 49-136 | |
| Hour-8 | Ceramic fibre | 89-110 | 70381 |
| | Brick structure | 60-167 | |

| Hour | Surface | Surface temperature (°C) | Heat loss (kcal/batch) |
|---|---|---|---|
| Hour-9 | Ceramic fibre | | 78754* |
| | Brick structure | | |
| Hour-10 | Ceramic fibre | 88-107 | 87126 |
| | Brick structure | 59-198 | |
| Hour-11 | Ceramic fibre | | 84137* |
| | Brick structure | | |
| Hour-12 | Ceramic fibre | 91-121 | 81148 |
| | Brick structure | 65-139 | |
| | | Total | 530799<br>(13.6%) |

Assuming the heat loss decreases gradually during cooling cycle of the kiln, Total heat loss = 1064510 kcal/batch *(27.2%)*

(2) Heat loss from inside refractories

Weight of refractories inside kiln = 1325 kg

Heat loss from inside refractories = 63812 kcal/batch (1.6%)

(3) Flue gas loss

Flue gas loss increases with time as it is a function of inside temperature of furnace, which increases during heating and soaking periods. Flue gas loss accounts for about 40% of total heat input to the furnace. After HSD firing is stopped following soaking, blower is kept running. The blower supplies cooling air, which carries away the heat through the chimney and cools down the material inside furnace. This heat carried away by the cooling air accounts for about 18% of total heat input. The following tables show the heat losses through flue gas and cooling air losses respectively.

*Assumptions:*

1. Flue gas analysis (measurement of $O_2$ and CO) was measured upto hour-6. For remaining hours of firing the corresponding readings equivalent to HSD firing rates are assumed.
2. The amount of air blown during cooling cycle is based on the actual air flow measured during heating cycle (based on $O_2$ and CO measurements)

### Flue gas heat loss

| Hour | Oxygen (%) | Carbon monoxide (ppm) | Flue gas temperature (°C) | Excess air (%) | Flue gas loss (kcal/batch) |
|---|---|---|---|---|---|
| Hour-1 | 5.4-8.7 | 195 | 105 | 66 | 10715 |
| Hour-2 | 3.3-6.7 | 487-1691 | 248-301 | 29 | 44749 |
| Hour-3 | 2.9-4.1 | 67-81 | 423-443 | 19 | 70448 |
| Hour-4 | 4.3-10.3 | 10-202 | 445-564 | 24 | 105952 |
| Hour-5 | 2.6-3.9 | 2-213 | 745 | 17 | 151638 |
| Hour-6 | 2.5-3.6 | 1-2 | 773-805 | 16 | 162178 |
| Hour-7 | 3.1 | 1.5 | 924 | 16 | 205752 |
| Hour-8 | 3 1 | 1.5 | 990 | 16 | 210172 |
| Hour-9 | 3 3 | 108 | 1024 | 17 | 201776 |
| Hour-10 | 5.0 | 1089 | 1030 | 29 | 138655 |
| Hour-11 | 5.0 | 1089 | 1007 | 29 | 123801 |
| Hour-12 | 5.0 | 1089 | 985 | 29 | 123423 |
| | | | | Total flue gas loss | 1549259<br>(40%) |

### Cooling air heat loss

| Hour | Flue gas temperature (°C) | Flue gas loss (kcal/batch) |
|---|---|---|
| Hour-14 | 774 | 105032 |
| Hour-15 | 681 | 92490 |
| Hour-16 | 605 | 80427 |
| Hour-17 | 572 | 75951 |
| Hour-18 | 539 | 70127 |
| Hour-19 | 510 | 66284 |
| Hour-20 | 457 | 58010 |
| Hour-21 | 410 | 51819 |
| Hour-22 | 368 | 45261 |
| Hour-23 | 333 | 40642 |
| | Total cooling air loss | 686043<br>(18%) |

Total loss through chimney = 2235302 kcal/batch (*58%*)

### (6) Heat loss due to dead weight of decker plates, saggars and trolley structure

| Material | Quantity (kg/batch) | Inlet temperature (°C) | Outlet temperature (°C) | Specific heat (kcal/kg°C) | Heat loss (kcal/hr) |
|---|---|---|---|---|---|
| Decker plates & pillars | 3192 | 32 | 325 | 0.186 | 174129 |
| Saggars | 779 | 32 | 325 | 0.164 | 37537 |
| Refractory bricks | 1431 | 32 | 325 | 0.164 | 68909 |
| Iron structure | | | | | |
| - Frame | 235 | 32 | 325 | 0.120 | 8276 |
| - Wheel | 80 | 32 | 325 | 0.120 | 2816 |
| | | | | Total heat loss | 291666 |

Heat loss due to trolley structure = 291666 kcal/batch (7.5%)

(7) Residual heat loss in products

Total production = 806 kg/batch

Outlet temperature of product = 325°C

Residual heat loss through the products = 41300 kcal/batch (1.1%)

Heat balance of shuttle kiln

| Component | Heat component | |
|---|---|---|
| | Kcal/batch | Fraction (%) |
| Heat loss for moisture removal in product | 39578 | 1.0 |
| Reaction heat | 178871 | 4.6 |
| Residual heat loss in product | 41300 | 1.1 |
| Heat loss in trolley, decker plates and saggars | 291666 | 7.5 |
| Structural loss | 1061598 | 27.1 |
| Heat loss from inside refractories | 63812 | 1.6 |
| Flue gas loss | 1549259 | 39.6 |
| Cooling air loss | 686043 | 17.5 |
| Total heat input | 3912127 | 100.0 |

Annexure 6.5

# Heat balance of tunnel kiln

## Heat balance of tunnel kiln

Heat input

HSD consumption = 478 lit/day (17 kg/hr)

GCV of HSD = 10900 kcal/kg

Heat input = 182306 kcal/hr

### (1) Structural loss

Ambient temperature = 36°C

### (a) Right surface

| Surface | Surface temperature (°C) | Surface area ($m^2$) | Heat loss (kcal/hr) |
|---|---|---|---|
| Entrance - Air curtain-1 | 44 | 0.3 | 37 |
| Air curtain - Thermocouple-1 | 52 | 0.5 | 111 |
| Thermocouple-1 - Air curtain-2 | 54 | 0.9 | 216 |
| Air curtain-2 to Thermocouple-2 | 59 | 1.0 | 342 |
| Thermocouple-2 - Preheating end | 63 | 14.1 | 5381 |
| Firing zone side-1 | 97 | 1.0 | 937 |
| Upto Thermocouple-3 | 65 | 1.8 | 771 |
| Thermocouple-3 - Thermocouple-4 | 79 | 2.7 | 1754 |
| Thermocouple-4 - Firing zone end | 60 | 2.1 | 704 |
| Firing zone side-2 | 128 | 1.0 | 1563 |
| Cooling zone - Air curtain-3 | 84 | 0.3 | 250 |
| Air curtain-3 - Thermocouple-5 | 64 | 0.5 | 193 |
| Thermocouple-5 - Air curtain-4 | 75 | 0.9 | 514 |
| Air curtain-4 - Thermocouple-6 | 50 | 7.2 | 1373 |
| Thermocouple-6 - Air curtain-5 | 45 | 7.5 | 889 |
| Air curtain 5 - Cooling zone end | 43 | 8.2 | 817 |
|  | Total | 49.9 | 15851<br>(8.7%) |

### (b) Top surface

| Surface | Surface temperature (°C) | Surface area ($m^2$) | Heat loss (kcal/hr |
|---|---|---|---|
| Entrance - Air curtain-1 | 47 | 0.4 | 55 |
| Air curtain - Thermocouple-1 | 49 | 0.6 | 103 |
| Thermocouple-1 - Air curtain-2 | 58 | 1.0 | 298 |

| Surface | Surface temperature (°C) | Surface area (m²) | Heat loss (kcal/hr) |
|---|---|---|---|
| Air curtain-2 to Thermocouple-2 | 68 | 1.1 | 536 |
| Thermocouple-2 - Preheating end | 86 | 15.7 | 12191 |
| Upto Thermocouple-3 | 90 | 4.0 | 3379 |
| Thermocouple-3 - Thermocouple-4 | 91 | 5.7 | 5015 |
| Thermocouple-4 - Firing zone end | 89 | 4.4 | 3633 |
| Cooling zone - Air curtain-3 | 77 | 0.4 | 237 |
| Air curtain-3 - Thermocouple-5 | 67 | 0.5 | 237 |
| Thermocouple-5 - Air curtain-4 | 48 | 1.0 | 160 |
| Air curtain-4 - Thermocouple-6 | 48 | 8.0 | 1294 |
| Thermocouple-6 - Air curtain-5 | 48 | 8.4 | 1356 |
| Air curtain-5 - Cooling zone end | 48 | 9.1 | 1479 |
| | Total | 60.3 | 29972<br>(16.4%) |

(c) Front end surface

Surface temperature = 44°C

Surface area = 1.1 m$^2$

Heat loss = 115 kcal/hr

(d) Left surface and back end surface

It has been assumed here that the heat loss from left surface is equivalent to right surface, and the heat loss from back end is equivalent to front end surface.

Total surface area of the kiln = 161 m$^2$

Total structural loss = 61673 kcal/hr (33.8%)

(2) Heat loss due to evaporation of moisture in greens = 3798 kcal/hr (2.1%)

(4) Heat loss due to dead weight of saggars and trolley structure

| Material | Quantity (kg/trolley) | Inlet temperature (°C) | Outlet temperature (°C) | Specific heat (kcal/kg) | Heat loss (kcal/hr) |
|---|---|---|---|---|---|
| Saggars | 290 | 42 | 200 | 0.154 | 6499 |
| Cement | 30 | 62 | 140 | 0.186 | 399 |
| Refractory bricks | 255 | 62 | 140 | 0.154 | 2814 |
| Iron structure | | | | | |
| - Frame | 115 | 53 | 79 | 0.120 | 331 |
| - Wheel | 40 | 53 | 79 | 0.120 | 115 |
| | | | | Total heat loss | 10157 |

Heat loss due to trolley structure = 10157 kcal/hr (5.6%)

(5) Residual heat loss in product = 2102 kcal/hr (1.1%)

(6) Flue gas loss and unaccounted heat loss

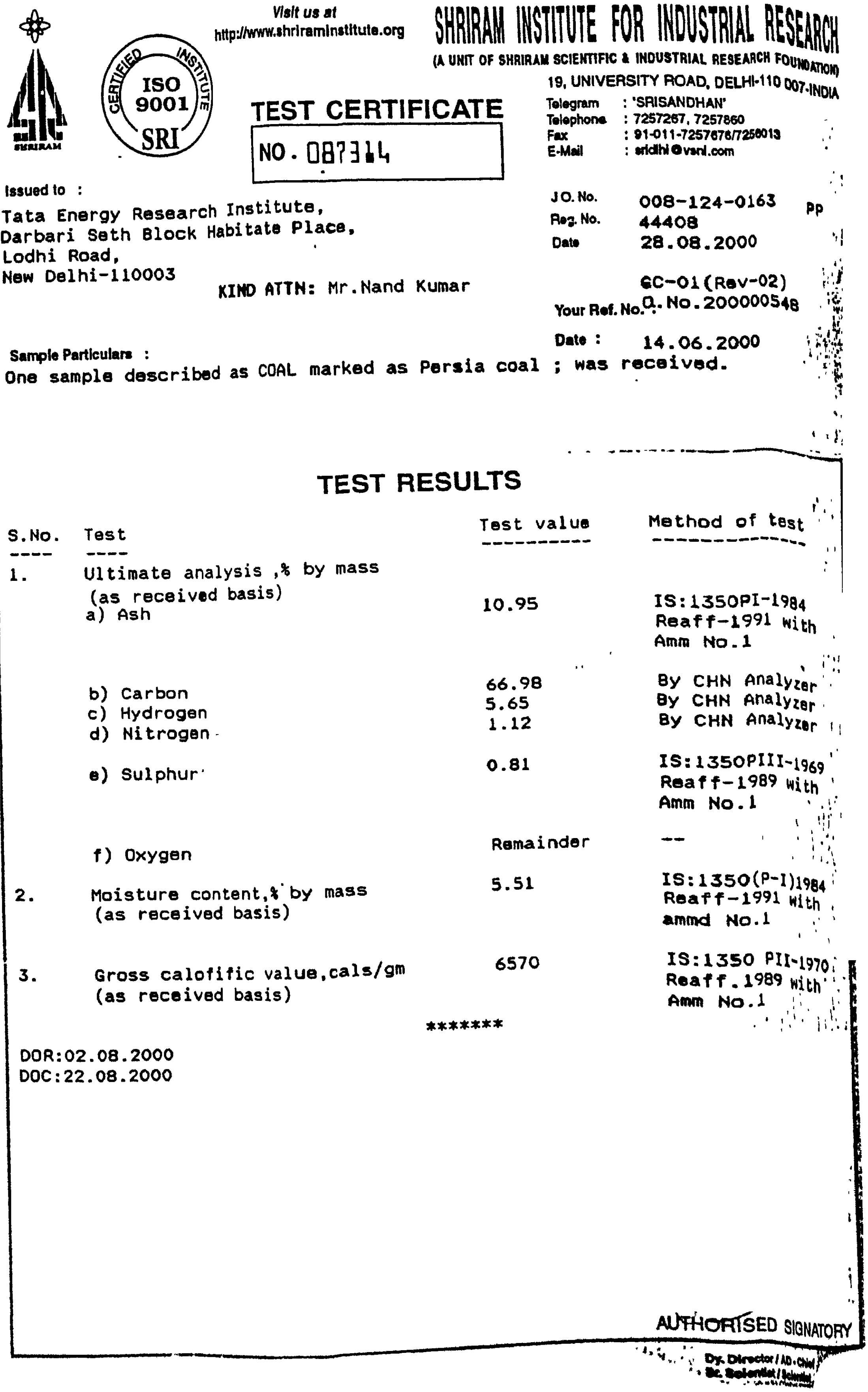
Flue gas loss and unaccounted losses (include heat loss to ground) were calculated as difference of total heat input and other measured heat losses.

Flue gas heat loss & unaccounted heat loss = 82196 kcal/hr (45.1%)

Heat balance of tunnel kiln

| Component | Heat component | |
|---|---|---|
| | Kcal/hr | Fraction (%) |
| Heat loss for moisture removal in product | 3845 | 2.1 |
| Reaction heat | 22333 | 12.3 |
| Residual heat loss in product | 2102 | 1.2 |
| Heat loss in trolley and saggars | 10157 | 5.6 |
| Structural loss | 61673 | 33.8 |
| Flue gas loss & unaccounted heat loss | 82196 | 45.1 |
| Heat input | 182306 | 100.0 |

Annexure 6.6



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Reg. No. 44408
Date 28.08.2000

GC-01(Rev-02)
Your Ref. No. : Q.No.200000548
Date : 14.06.2000

**Sample Particulars :**
One sample described as COAL marked as Persia coal ; was received.

## TEST RESULTS

| S.No. | Test | Test value | Method of test |
|---|---|---|---|
| 1. | Ultimate analysis ,% by mass (as received basis) | | |
| | a) Ash | 10.95 | IS:1350PI-1984 Reaff-1991 with Amm No.1 |
| | b) Carbon | 66.98 | By CHN Analyzer |
| | c) Hydrogen | 5.65 | By CHN Analyzer |
| | d) Nitrogen | 1.12 | By CHN Analyzer |
| | e) Sulphur | 0.81 | IS:1350PIII-1969 Reaff-1989 with Amm No.1 |
| | f) Oxygen | Remainder | -- |
| 2. | Moisture content,% by mass (as received basis) | 5.51 | IS:1350(P-I)1984 Reaff-1991 with ammd No.1 |
| 3. | Gross calofific value,cals/gm (as received basis) | 6570 | IS:1350 PII-1970 Reaff.1989 with Amm No.1 |

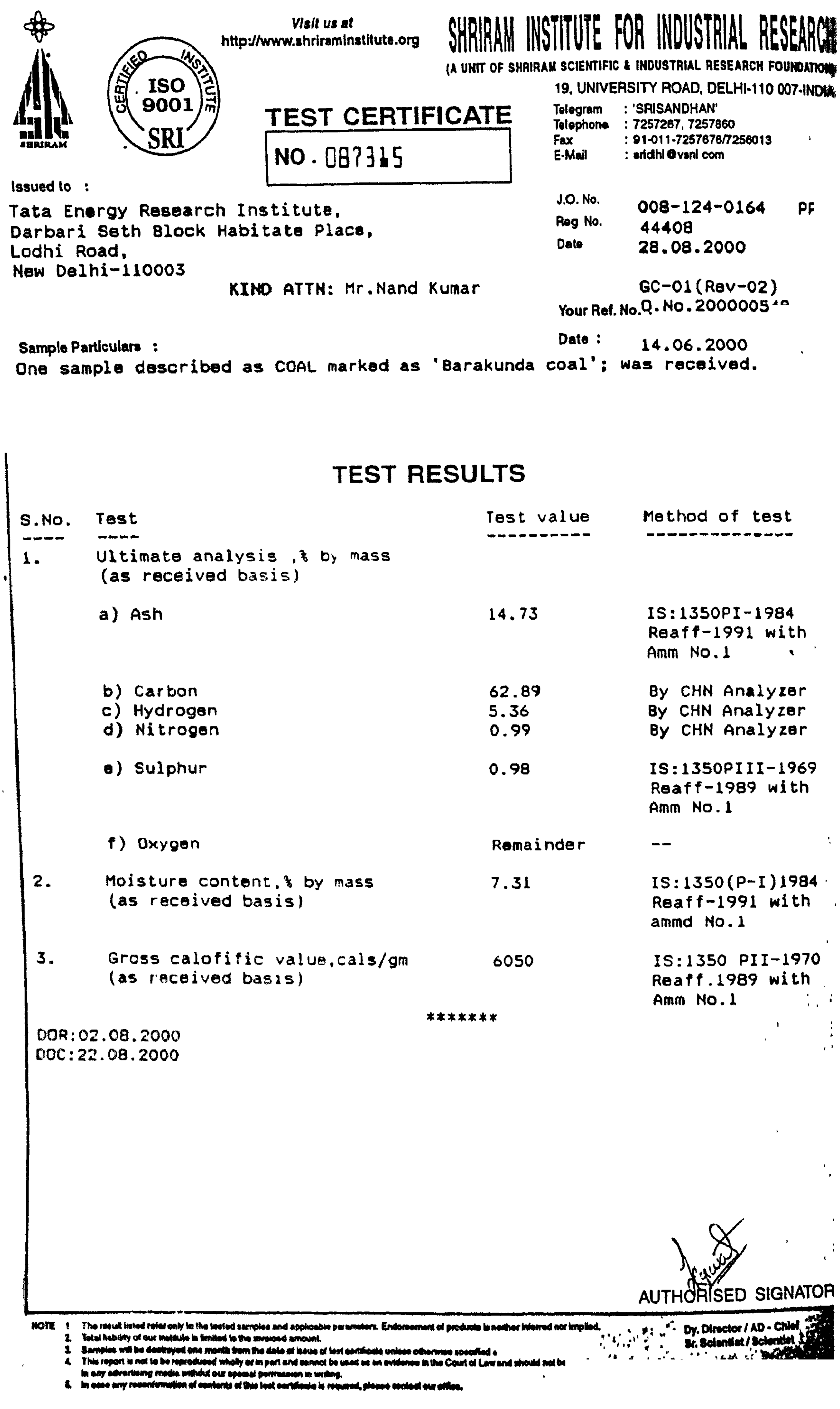
*******

DOR:02.08.2000
DOC:22.08.2000

AUTHORISED SIGNATORY

Dy. Director/AD-Chief
Sr. Scientist/Scientist

Annexure 6.6A



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Reg No. 44408
Date 28.08.2000
GC-01(Rev-02)
Your Ref. No. Q.No.2000005
Date : 14.06.2000

Sample Particulars :
One sample described as COAL marked as 'Barakunda coal'; was received.

## TEST RESULTS

| S.No. | Test | Test value | Method of test |
|---|---|---|---|
| 1. | Ultimate analysis ,% by mass (as received basis) | | |
| | a) Ash | 14.73 | IS:1350PI-1984 Reaff-1991 with Amm No.1 |
| | b) Carbon | 62.89 | By CHN Analyzer |
| | c) Hydrogen | 5.36 | By CHN Analyzer |
| | d) Nitrogen | 0.99 | By CHN Analyzer |
| | e) Sulphur | 0.98 | IS:1350PIII-1969 Reaff-1989 with Amm No.1 |
| | f) Oxygen | Remainder | -- |
| 2. | Moisture content,% by mass (as received basis) | 7.31 | IS:1350(P-I)1984 Reaff-1991 with ammd No.1 |
| 3. | Gross calofific value,cals/gm (as received basis) | 6050 | IS:1350 PII-1970 Reaff.1989 with Amm No.1 |

*******

DOR:02.08.2000
DOC:22.08.2000

AUTHORISED SIGNATOR

Dy. Director / AD - Chief
Sr. Scientist / Scientist

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